NSTS 07700, Volume XIV,

Appendix 9

System Description and Design Data -

Intravehicular Activities

DESCRIPTION OF CHANGES TO

SYSTEM DESCRIPTION AND DESIGN DATA - INTRAVEHICULAR ACTIVITIES
NSTS 07700, VOLUME XIV, APPENDIX 9

CHANGE NO.	DESCRIPTION/AUTHORITY	DATE	PAGES AFFECTED
REV J	Baseline Issue/CR D07700-014-009-01.	6/1/89	ALL
REV K	Complete revision; the following CR's are included: D07700-014-009-02, D0700-014-009-03, D07700-014-009-04.	12/16/92	ALL
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Preface

This document is designed to be used in conjunction with the series of documents illustrated in Figure 1. This information source describes the constraints, limitations, and capabilities involved in performing intravehicular activities (IVA) for the Space Shuttle Program (SSP). It also serves as a set of IVA equipment design requirements.

Specific agreements for IVA and IVA equipment design must be specified in the individual Payload Integration Plan (PIP).

Configuration control of this document will be accomplished through the application of procedures contained in Mission Integration Control Board Configuration Management Procedures, NSTS 18468, current issue.

Questions and recommendations concerning this document should be addressed to:

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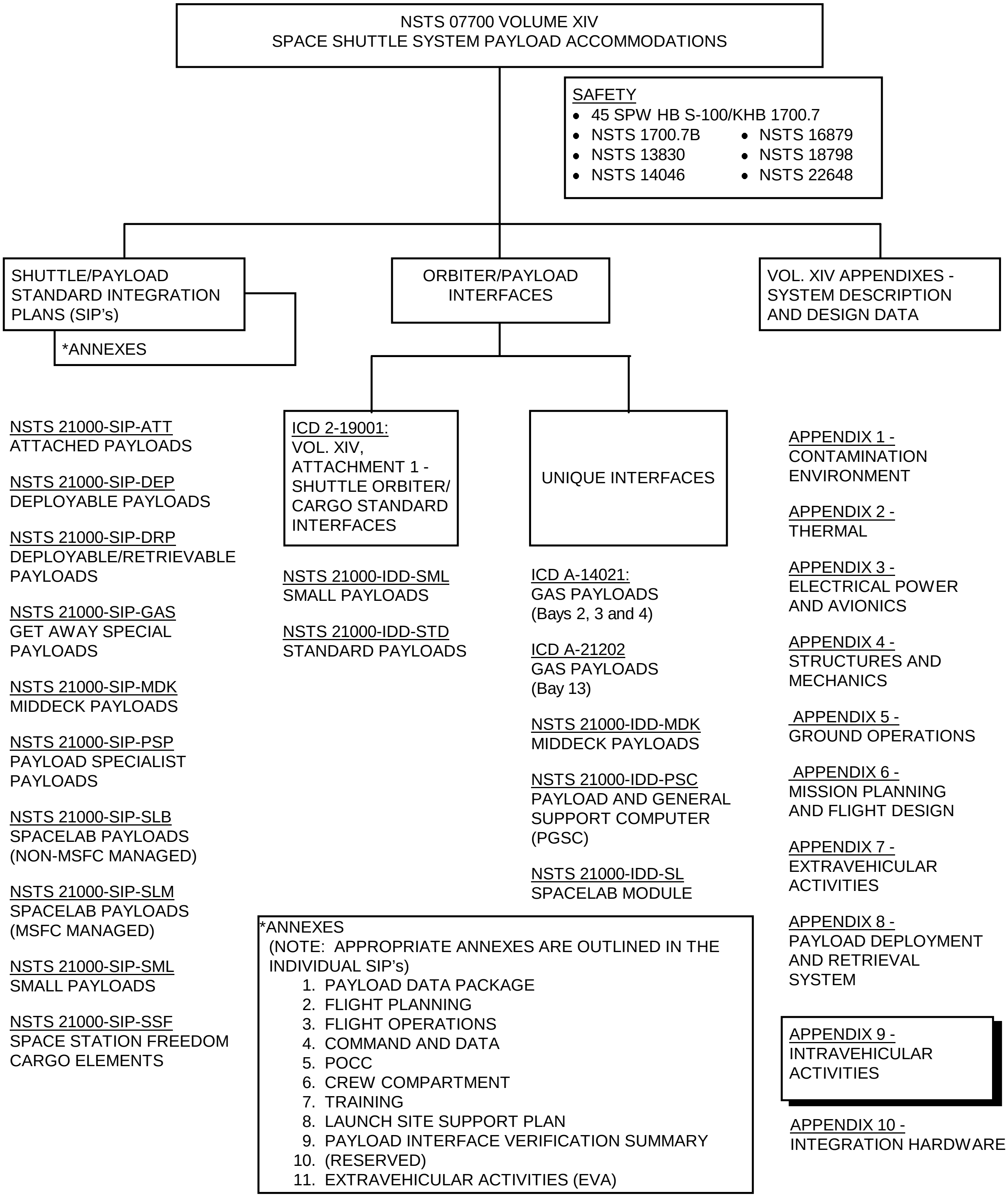

Figure 1.- Space Shuttle Program customer documentation tree.

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Introduction

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1.1 General

The Space Shuttle Program (SSP) offers a variety of services to payload customers in addition to transportation to and from orbit. These services include intravehicular activities (IVA) performed during planned on-orbit payload operations. Crew-related payload activities during ascent and descent mission phases are very limited, and must be specifically negotiated with the SSP.

This appendix documents SSP IVA provisions, manned systems, and inflight maintenance design requirements. These requirements apply to payloads flown in the orbiter middeck, payloads flown in a man-tended facility, and to the facility itself. In this appendix, a man-tended facility is defined as a module certified as a man-rated facility to be inhabited while docked with the orbiter, during which the crewmember will be in a shirt-sleeve environment.

All IVA design requirements are identified in this document. Safety Policy and Requirements for Payloads Using the Space Transportation System, NSTS 1700.7B is referenced for safety requirements. Space Shuttle System Payload Accommodations, NSTS 07700, Volume XIV (and appendixes), Shuttle Orbiter/Cargo Standard Interfaces, ICD 2-19001, and Shuttle/Payload Interface Definition Document for Middeck Payload Accommodations, NSTS 21000-IDD-MDK, define Space Shuttle payload accommodations and additional design requirements.

Commercially developed payloads may use Man-Systems Integration Standards, NASA-STD-3000, as a guideline for achieving design goals consistent with Space Shuttle operations and efficient, productive, safe crew interfaces within the Space Shuttle flight environment. NASA-STD-3000 also includes supporting data for design requirements identified in this appendix, other design considerations, and design solution examples.

1.2 Background of Intravehicular Activities

National Aeronautics and Space Administration (NASA) payload IVA capabilities have developed and expanded dramatically during the past 20 years from experience gained in the Gemini, Apollo, Apollo/Soyuz, Skylab, and Space Shuttle programs. Proof of the ability to perform experiment procedures (as well as maintenance and repair operations) has been demonstrated throughout NASA's manned programs, and has expanded with use of the Space Shuttle and the Spacelab module.

The following examples illustrate the scope of IVA operations and inflight maintenance (IFM) which may be planned and performed for payload support:

- Activation/deactivation, operation, and monitoring of payload equipment
- Installation, removal, and transfer of film cartridges or videocassettes, material samples, and instrumentation (semi-operational and servicing)
- Replacement and inspection of payload equipment and instrumentation
    - Inspection and photography of payload experiments
    - Connection, disconnection, and stowage of experiment equipment
- Activation and deactivation of customer-provided crew modules
- Performance of malfunction procedures
- On-orbit payload hardware repair
- Remedial repair and repositioning of equipment

1.3 Definition and Categories of Intravehicular Activities

IVA includes crew activities which occur within the orbiter crew compartment or a customer-provided pressurized module such as an attached pressurized module in the payload bay or a free flying module docked with the orbiter.

IVA operations include module activation/ deactivation, on-orbit operations, and monitoring while hatches are open allowing free access to the orbiter. During IVA operations, hatches which either separate module elements or separate a module element from the orbiter must remain open in accordance with NSTS 1700.7B.

The two categories of payload IVA discussed in this document are operations and IFM.

Nominal operations include IVA activity (other than IFM) planned prior to launch and included in the nominal mission timeline. This includes performance of normal procedures such as unpacking, assembly, powering up, etc.

Off-nominal operations include performance of backup, malfunction, contingency, or emergency procedures which do not involve hardware modification or repair.

IFM includes on-orbit hardware maintenance or repair activities conducted by the crew within a pressurized vessel or payload module to keep the payload operable or to return it to operability. IFM normally involves removal of payload panels, mating and demating of electrical connectors, or replacement of line replaceable units (LRU's).

Intravehicular Activities Provisions

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2.1 Introduction

This section addresses SSP IVA provisions for orbiter crew compartment payloads/experiments and customer-provided pressurized modules with examples utilizing Spacelab configuration.

Standard Space Shuttle/payload accommodations and provisions for contamination, thermal, electrical power and avionics, structures and mechanics, and ground operations defined in NSTS 07700, Volume XIV (and its appendixes) apply to SSP IVA provisions and are not repeated here. Customers should also consult ICD 2-19001 and NSTS 21000-IDD-MDK for complete SSP IVA provisions.

2.2 Structural Interface Provisions

SSP structural accommodations are defined in System Description and Design Data - Structures and Mechanics, NSTS 07700, Volume XIV, Appendix 4.

2.2.1 Airlock

The primary interface between the orbiter and a customer-supplied module is the orbiter airlock and adaptors. The airlock allows extravehicular activity (EVA) operations without the necessity for cabin decompression or for decompression of an attached pressurized habitable module in the payload bay. Although it is primarily an EVA device, it serves as a translation path for IVA.

2.2.2 Tunnel Adaptor and Module Transfer Tunnel

The tunnel adaptor and/or module transfer tunnel may be used by the payload customer. Use of this flight-certified hardware must be negotiated with the SSP as an optional service.

The tunnel adaptor is a cylindrical structure developed for Spacelab module missions to attach the module transfer tunnel (Figure 2-1) to the orbiter crew compartment aft bulkhead. The tunnel adaptor and module transfer tunnel provide a translation path for crewmembers from the orbiter to a habitable module in the payload bay. The tunnel adaptor has three ports. The third port ensures EVA capability even when attached to a customer-supplied module. Use of the tunnel adaptor and module transfer tunnel are payload customer options.

The payload customer may negotiate in the Payload Integration Plan (PIP) to have the SSP provide an adaptor specifically designed and built to interface with a module-unique payload-provided translation tunnel or structure.

2.2.3 Hatches

The airlock and tunnel adaptor employ a universal D-shaped hatch. Each hatch has a clear passageway 40 inches (101.6 cm) in diameter, and one flat side which reduces the minimum dimension of the hatch opening to 36 inches (91.4 cm). The hinge geometry is designed to maintain compatibility with pressure seals and position the hatch open without obstructing the passage. The latch mechanism is designed to produce sufficient force on the seals to maintain compartment integrity during thermal or structural deflections.

2.3 Atmosphere Provisions

The following paragraphs describe atmosphere revitalization requirements.

2.3.1 Prelaunch

Attached modules which have been closed out prior to launch minus 96 hours require atmospheric purging in the form of scrubbing, filtering, or other provisions prior to on-orbit ingress. Extended launch holds will result in an additional purge.

Purge duration and hold capability will vary according to payload configuration and purge method. This requirement will be documented in PIP Annex 9.

2.3.2 Flight

Responsibility for provision, maintenance, and revitalization of module atmosphere while attached to the orbiter shall be as described in this document. A ducting interface may be provided by the SSP as an optional service for exchange and revitalization of module atmosphere. Any consumables required for inflight customer module purging and repressurization will be supplied by the customer.

2.3.3 Module Transfer Tunnel

The module transfer tunnel described above may be used with the tunnel adaptor to provide passage and atmosphere circulation between the module and the orbiter atmosphere revitalization system (ARS) as depicted in Figure 2-1. Airflow is generated by the tunnel fan, which pumps air at approximately 130 ft^3/min from the tunnel into the module via the tunnel fan duct. A backflow of air is induced into the tunnel from the module to the orbiter. The orbiter receives only part of this airflow (approximately 53 ft^3/min) due to the tunnel fan duct intake located directly downstream of the tunnel adaptor. This intake pulls in approximately 77 ft^3/min of air. This air exchange is essential to replenishment of oxygen and nitrogen in the crew compartment and module during on-orbit flight phases while the module is attached to the orbiter with hatches open.

The orbiter pressure control system can be configured to either supply oxygen and nitrogen or inhibit supply of either and allow the module to provide that component. Scrubbing and filtration provisions for the customer-supplied module are required as defined in NSTS 1700.7B. Lights are located in various places along the tunnel with individual controls for each light.

2.4 Habitability Provisions

Habitability functions, such as launch and entry seating, food preparation, hygiene, waste management, exercise, and sleeping accommodations will be provided by the SSP.

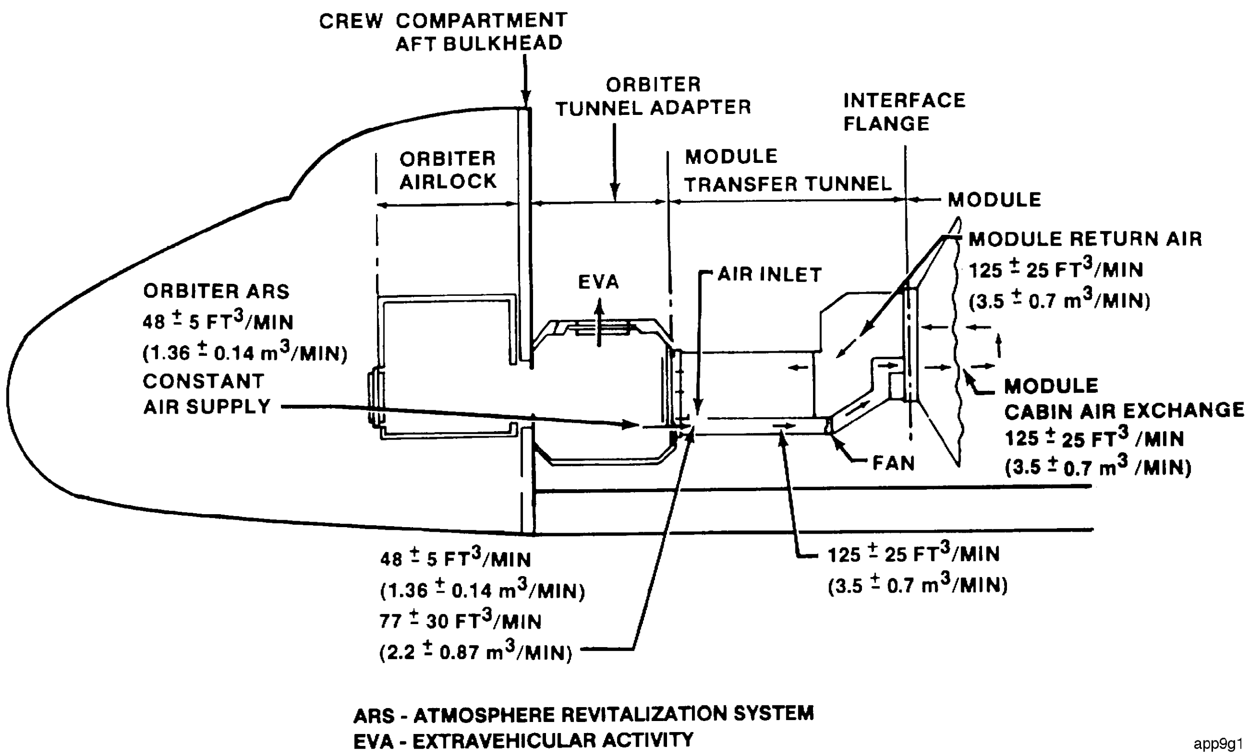

Figure 2-1.- Orbiter tunnel adaptor and module transfer tunnel.

Habitable Module Ingress Factors

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A safe and habitable environment must be ensured prior to IVA operations. Requirements for atmosphere sampling and verification prior to hatch opening, cross contamination, fire detection and control, and caution and warning are defined in NSTS 1700.7B.

NSTS 1700.7B also specifies that customer-supplied habitable payloads (modules) shall provide a means for visual inspection of the interior of the module prior to hatch opening and crew ingress.

Intravehicular Activities Mission Integration

4

4.1 General

The SSP payload integration process is employed for integrating all types of payloads, from the simplest orbiter middeck experiments to complex customer-supplied habitable modules, with experiments. All customer IVA requirements are identified and documented during development of the payload-specific PIP and interface control document (ICD).

For development of complex customer-provided habitable modules, consideration of IVA requirements at the earliest stages of payload design is necessary. Concurrent establishment of an effective formal design review with the SSP (including engineering and operations personnel with IVA experience) is also required.

4.2 Development Responsibilities

Development of a customer-provided habitable module requires a series of IVA mission support activities:

- Hardware design
- Software design support (limited to general purpose computer (GPC) crew display configuration and evaluations for other than GPC displays)
- Design reviews
- Safety requirements
- Procedures development
- Hardware testing and certification
- Crew activity planning
- Crew training
- Real-time support

SSP and customer responsibilities for these support activities are specified in Table 4-1.

4.2.1 Hardware Design

Hardware design is the responsibility of the customer. SSP and customer-provided interface hardware to accomplish payload IVA tasks must be identified in the PIP. One set of training hardware is required.

4.2.2 Design Reviews

The customer must perform a Preliminary Design Review (PDR) and a Critical Design Review (CDR) of customer-provided hardware with SSP IVA engineering, operations, and safety representatives. SSP support of these reviews is required and is charged as an optional service. For complex payload systems, it is important that the customer take advantage of SSP flight experience early in the design effort. SSP participation in PDR and CDR activities does not constitute approval of the design and is not a substitute for later activities in the standard SSP integration process, including safety assessments.

TABLE 4-I.- IVA DEVELOPMENT RESPONSIBILITIES

Activity	User	SSP
Payload hardware design for IVA tasks	R	C*
Operational evaluation of design	R	C*
Operational evaluation of hardware and software display configuration	R	C
IVA 1-g evaluations	C	O
IVA WETF evaluations	C	O*
Payload mockup design and fabrication	R	C
Hardware certification	R	C
Annex data submittals	R	C
Flight data file development	C	R
IVA crew payload-specific training for the customer-supplied module and experiments in the module	R	C
Orbiter/payload integrated IVA crew training	C	R

R = responsibility
C = consultation required
O = provided by the SSP
* = optional service

WETF - Weightless Environment Training Facility

4.3 Integration Requirements

Unique requirements related to Space Shuttle integration are discussed in the following paragraphs.

4.3.1 Prototype and Mockup Hardware Evaluations

All payload hardware requiring a crew interface must undergo early iterative evaluations using customer-supplied mockups or prototypes. The majority of these evaluations will be conducted in a 1-gravity (g) environment, and may use the orbiter full fuselage trainer or crew compartment trainer as an engineering test bed for fit and function checks. Use of these 1-g facilities for hardware evaluations is a standard service. Prototypes and mockups should be evaluated before engineering designs are finalized to prevent costly changes. Prototype hardware can often be adapted to support subsequent crew training.

Complicated or unique hardware may require evaluation in a neutral buoyancy facility such as the Weightless Environment Training Facility (WETF). For information on the WETF, refer to Weightless Environment Training Facility General

Operating Procedures, JSC 16908. Use of the WETF is an optional service.

4.3.2 Crew Training

Orbiter/payload integrated crew training for IVA is the responsibility of the SSP. This training covers the airlock, module activation and deactivation, and IVA-related orbiter systems and operations. It is conducted in classrooms, high fidelity mockups, and part-task trainers.

Like the design effort, payload training requirements depend on the complexity and criticality of the given task. Training requirements are minimized for tasks within recognized crewmember capabilities and constraints in the microgravity environment. If the task is safety critical with a low margin for error, or if the sequence of events is time critical for task accomplishment, unique training may be required.

Detailed payload procedure IVA crew training for customer-supplied habitable modules will normally be conducted by the customer using high fidelity payload mockups and trainers, and training articles with a level of fidelity appropriate to the complexity and criticality of the task. The SSP can develop and procure training articles for the customer as an optional service. Simplicity of the task, commonality of hardware with proven designs, and use of proven techniques may lower the cost of crew training.

4.3.3 Real Time Support

The SSP is responsible for implementation of mission IVA requirements. Real time ground support is provided and includes input from the customer organization.

The payload operations support concept, flight control team structure, responsibilities, and joint operations interface procedures are developed and negotiated by the SSP and customer during the PIP annex process, and are documented in Flight Operations Support Annex, PIP Annex 3.

4.3.4 Documentation

Data related to detailed payload customer IVA requirements, tasks, procedures, and equipment for individual payloads/experiments are contained in the PIP annexes as follows:

- Annex 1: Payload Data Package - Payload configuration, mass properties data, schematics, drawings, photographs and radio frequency (RF) radiation data
- Annex 2: Flight Planning - IVA information required for flight planning and timelining of IVA tasks, attitude and pointing constraints, and photo/television (TV) requirements
- Annex 3: Flight Operations Support - Identification of all IVA tasks, timelines and procedures for conducting normal experiment and payload operations, backup and malfunction procedures, contingency or emergency procedures, go/no-go criteria for flight implementation, payload data requirements, and required tools or support equipment
- Annex 6: Crew Compartment - Crew interface, displays and controls, panel configuration and labeling, stowage requirements, translation paths, and module configuration layout
- Annex 7: Training - Identification of IVA training activities, payload modeling, and mockup requirements

Intravehicular Activities Design Requirements and Constraints

5

5.1 General

This section details specifications for design of IVA interfaces and accommodations. These requirements are directed toward design of habitable modules and man/machine interfaces for crew operation in a microgravity environment.

IVA hardware must be designed to operate under the conditions described in this appendix and meet flammability, offgassing, and other safety requirements specified in NSTS 1700.7B. Consult NSTS 07700, Volume XIV (and its appendixes), ICD 2-19001, and NSTS 21000-IDD-MDK for complete design requirements.

NASA-STD-3000 is the reference document for the human-to-equipment interface for payloads flown in man-tended facilities and for the facility itself. It provides extensive information on biomechanics, human resources and performance, architectural considerations, and design guidance for equipment, controls, and restraints.

The following general IVA constraints shall apply to payload IVA design:

a. IVA operations will be developed using the capabilities, requirements, definitions and specifications set forth in this appendix.

b. IVA is not constrained to ground communication periods.

c. Payloads that require IVA operations must size access corridors and work areas to allow IVA crewmembers to perform the required IVA tasks safely and with adequate mobility.

d. Customer-supplied modules will be sealed off from the orbiter prior to EVA prebreathe activities; crewmembers may not inhabit the module during EVA.

e. To ensure that payload configuration for safe orbiter entry is accomplished in approximately the same time interval as the orbiter can be prepared for contingency return, the following design provisions for rapid safing are required. Neither payload configuration nor IVA payload operations will inhibit a rapid return of the IVA crewmember to the orbiter crew compartment from any location in the module. Safing shall be accomplished as rapidly as possible, and must be compatible with closing the payload bay doors within 20 minutes and deorbit orbital maneuvering system (OMS) firing within 30 minutes. Provisions to meet these time constraints shall be at least single-fault tolerant. Provisions for total safing shall remain two-fault tolerant. See NSTS 1700.7B for fault tolerance definitions.

f. The size of the airlock, tunnel adaptor, and associated hatches limits the external dimensions of packages that can be transferred.

g. Payload components which are operationally sensitive or susceptible to inadvertent damage or contamination by an IVA crewmember shall be guarded or otherwise protected or located in work areas away from IVA workstations and translation paths.

h. The availability of crew time during a mission is determined by numerous factors. The constraints used to develop crew timelines are defined in Crew Scheduling Constraints, JSC 22359. The principal considerations that drive crew schedules are orbiter operational activity, crew physiological factors, and payload requirements. Mission duration and number of crewmembers are determined by the SSP.

5.2 Hatches

Hatches for habitable modules shall be no smaller than the orbiter airlock hatch. NSTS 1700.7B contains additional hatch design requirements.

All required interfaces (communications, power, cooling, TV, telemetry, and ventilation) between the orbiter and a customer-provided module must be achievable without EVA.

5.3 Translation Paths

The customer shall provide a minimum translation path for the crewmember of 32 inches (81 cm) diameter for moving between crew habitable modules through interconnecting tunnel structures (Figure 5-1).

Requirements for an EVA translation path past the habitable module for access to other payloads and orbiter work areas are contained in System Description and Design Data - Extravehicular Activities, NSTS 07700, Volume XIV, Appendix 7.

5.4 Mobility Aids and Crew Restraints

Crew restraint provisions (e.g., handholds and handrails) shall be provided by the customer along translation paths and in planned work areas to prevent drifting and allow initiation and termination of movement. Such devices shall not restrict minimum translation path diameter. Restraints are also to be used in areas where force may be applied by a crewmember to prevent reactionary motion which would degrade task performance.

When properly designed and located, handholds and handrails serve as convenient locations for temporary restraint of loose equipment, and may be utilized to protect payload components from inadvertent damage by the crew. Some structural components may double as translation or mobility aids if suitably identified. Handrails must be painted yellow for rapid identification by the crew. Payload designers should consult the SSP for recommended handhold and handrail locations.

Proper restraint of IVA crewmembers and equipment at the worksite is mandatory to ensure maximum capability. Adequate restraint allows two-handed operations and is a factor in preventing crew fatigue. Use of restraint provisions is an essential part of basic training.

Use of handholds and handrails may be adequate for low force, brief tasks such as inspection, monitoring, and switch activation. Foot restraints have proven the most effective restraint system for IVA functions which require force application, precise positioning, and/or long periods of time at a particular workstation.

NASA-STD-3000 contains guidelines for designing mobility aids and crew restraints.

5.5 Crew and Equipment Safety

Payload designs shall meet the requirements of NSTS 1700.7B, protecting the crew from electrical, fluid, radiation, mechanical, chemical, and other hazards. Hazards and controls shall be identified through the SSP safety review process.

A fire protection system and module atmosphere venting capability shall be provided as part of the customer-supplied habitable module, in accord with the requirements of NSTS 1700.7B.

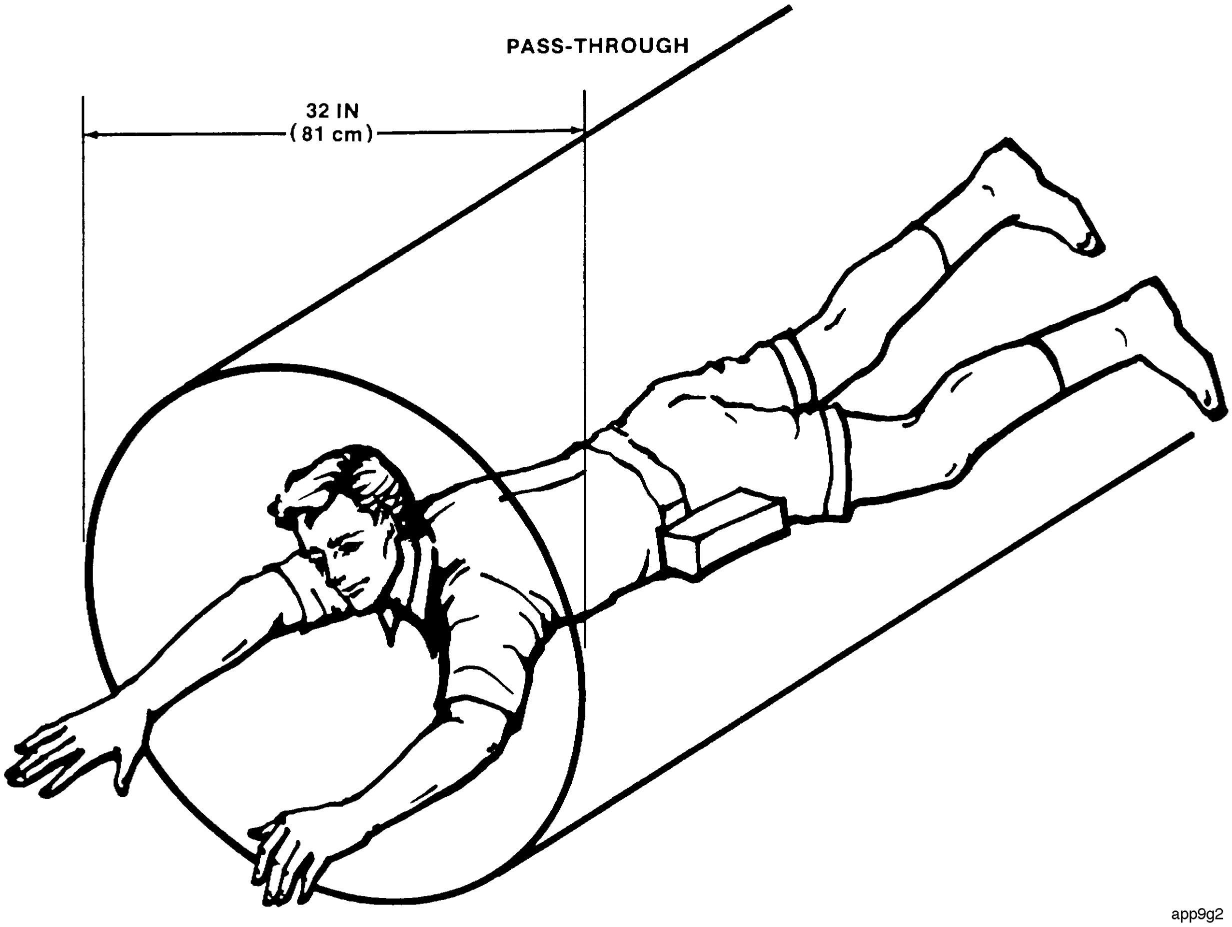

Figure 5-1.- Minimum translation path dimensions for microgravity (one crewmember in light clothing)

A major safety concern in IVA design is the compatibility of payload systems and structures with the crewmember. Payload equipment, structures along translation routes, worksite provisions, and items requiring crewmember contact must be designed to preclude sharp edges and protrusions or be covered to protect the crewmember. Rounding and curling criteria relative to sharp edges and protrusions are illustrated in Figure 5-2. Sharp edge inspections shall be performed on all components.

Customer payloads that include sharp objects (such as syringes) must give special consideration to configuration, containment, storage, materials, and procedures. Customers shall submit hazard controls through the SSP safety review process.

5.6 Hazard Identification

Indicator lights shall conform to Human Engineering Design Criteria for Military Systems, Equipment, and Facilities, MIL-STD-1472D. Hazards shall be physically identified by markings, labeling, and coloring as follows.

5.6.1 Color Coding

Only one hue within a color category (e. g. reds, greens) shall be used in a given coding scheme, and that color shall always be associated with a single meaning. No more than 9 colors, including white and black, shall be used in a coding system. Color coding shall not be used as a primary method of identification where lighting is insufficient in quantity or spectral characteristics.

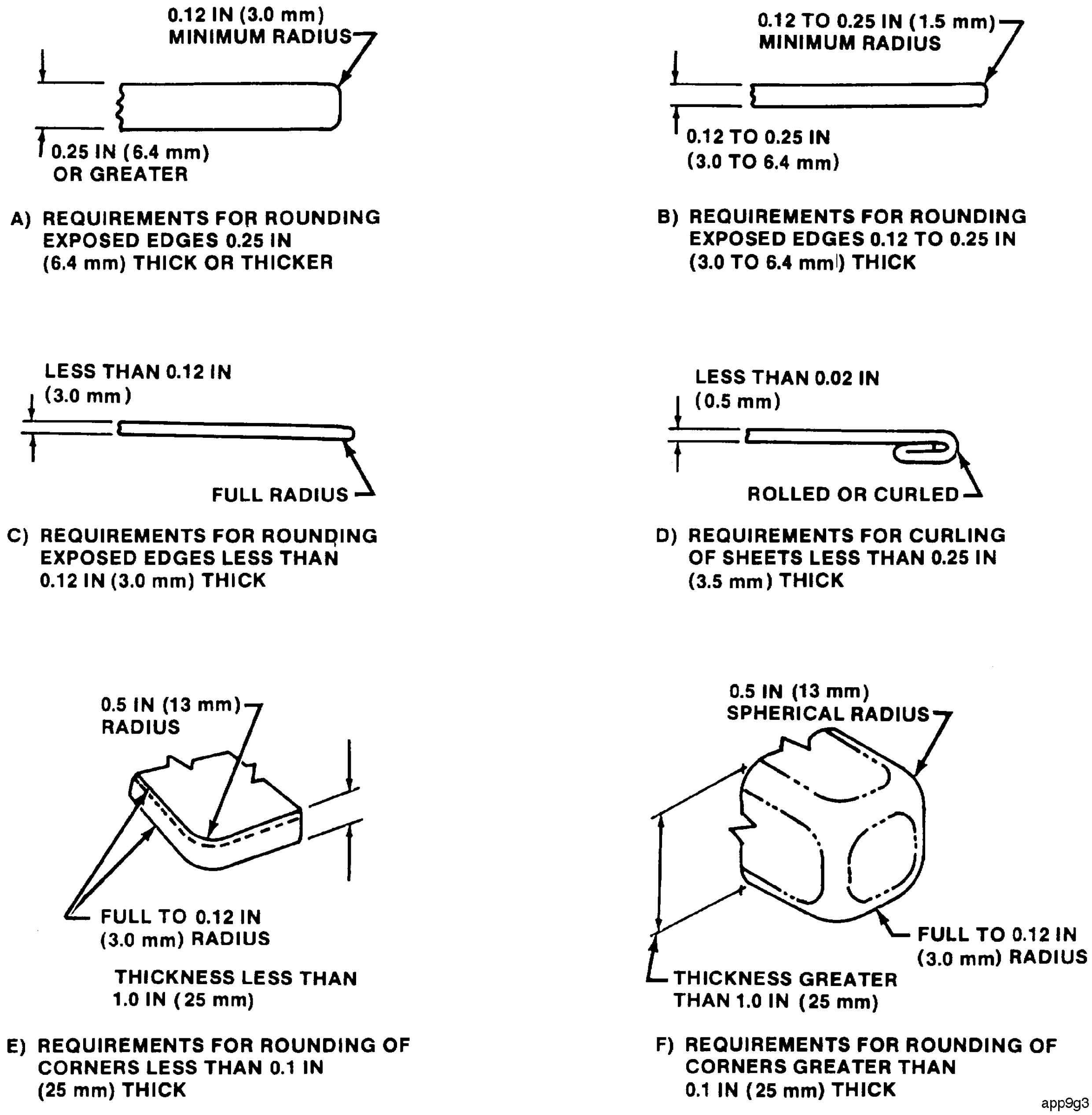

Figure 5-2.- Rounding and curling criteria.

The following colors (as specified in Colors, Federal Standard 595) shall be utilized for the purposes indicated.

a. Red #21105 (or #11302) - Emergency, warning, and master alarm lights; safety controls; critical controls requiring rapid identification for emergency shutdown; control panel outline of a functionally critical emergency nature. (Under ambient red lighting, use orange-yellow and black striping)

b. Yellow #33538 - Caution; emergency exits; safety controls associated with emergencies of a less critical nature

c. Yellow #33538 with black #37038 stripe - Immediate access; exit releases

d. Orange #32246 - Hazardous moving parts; machinery; start switches, etc.

e. Green #14187 - Important and frequently operated controls with no urgent or emergency implications

f. Green #14260 (sage) - First aid and survival

g. Blue # 25102 (or #15177) - Advisory (not recommended for general use)

h. Purple #37142 (magenta) - Radiation hazard

To avoid confusion by color-deficient observers, do not use the color green if the color scheme uses more than six colors. If six or fewer colors including green #14260 and yellow are used, yellow #23655 shall be substituted for #33583. Use of red and green within the same color coding system should be avoided.

5.6.2 Caution and Warning Labeling

Caution and warning labels are required to identify potentially undesirable conditions.

a. Caution and warning labels shall identify the type of hazard and the action that would prevent its occurrence.

b. Caution markings shall be located in a position that permits sufficient opportunity for the crew to avoid the hazard, and shall be large enough to be clearly legible from all normal viewing distances.

c. All immediate action controls, buttons, and small handles or levers requiring immediate access shall have panel backgrounds colored as specified in paragraph 5.6.1. Large handles or levers shall be colored on the handle or lever itself.

d. Emergency use items (e. g., repair kits, emergency lighting, fire extinguishers, etc.) shall display a unique marking (EMERGENCY USE) surrounded by diagonal yellow and black stripes either on the item or adjacent to it.

Emergency use items within a stowage container shall have diagonal striping on the door of the container, and titles of the emergency items shall be listed on the label instead of the words EMERGENCY USE.

e. Warning stripes shall be alternating yellow #33538 and black #37038 as described in Federal Standard 595, beginning and ending with yellow. Black stripes shall not be less than 0.065 inches (1.6 mm) wide. Yellow stripes shall be at least twice the width of the black stripes. Striping shall be applied at a 45 degree angle rotated clockwise from the vertical.

f. Payloads containing a liquid, gas, or dust that has the potential of escaping into the habitable volume shall have a label as defined in paragraph 5.6.3 to allow immediate response in the event of a toxic/irritant spill.

NASA-STD-3000 contains guidelines for letter size, spacing, and preferred font styles.

5.6.3 Toxic Labeling Standard

Decals will be utilized for identifying toxic hazard potential as defined in Table 5-I. Colors and numbers are required for immediate crew response to substance spills (see Figure 5-3).

These decals can be easily distinguished from the color coding requirements in paragraph 5.6.2. The payload integration manager can assist the customer in ordering required decals for the payload, based on the recommendation of the JSC toxicologist and JSC Safety Review Panel.

Table 5-I.- HAZARDOUS SPILL LEVELS

Color/ Level	State	Flammability	Systemic/ internal damage	Irritancy	Criticality level	Summary of hazard level
Red 4	Gas, volatile liquid, or fumes that are not containable by a cleanup crew. The ARS will be used to decontaminate. The 5-micron surgical masks will not protect the crew. Either quick don masks or SEBS is required.	May be capable of producing flammable vapors or fine mist in sufficient quantity to produce a hazard.	Appreciable effects on coordination, perception, memory, etc., or potential for long term (delayed) serious injury (e.g., cancer), or may result in internal tissue damage.	Moderate to severe irritation with potential for long-term crew performance decrement (for eye only hazards, there must be a risk of permanent eye damage). Note: Will require therapy.	Catastrophic	Catastrophic hazard (capable of causing disabling injury) not containable by a cleanup crew, with potential for systemic toxicity, moderate to severe irritation, tissue damage, or production of flammable vapors. Surgical masks will not, combined with goggles and gloves, protect the crew. Either quick don masks or SEBS required while the ARS decontaminates. No provision for severe skin irritation or absorption. Example: Metal vapor like mercuric iodide.
Orange 3	Either a solid or nonvolatile liquid which can be contained by a cleanup crew and disposed of. Surgical masks and gloves will not protect the crew. Either quick don masks or SEBS and gloves required.	Capable of producing flammable vapors or fine mist in sufficient quantity to produce a hazard.	Appreciable effects on coordination, perception, memory, etc., or potential for long-term (delayed) serious injury (e.g., cancer), or may result in internal tissue damage.	Irritation may accompany systemic toxicity concerns, however, irritancy alone does not cause a level 3.	Catastrophic	Catastrophic hazard (capable of causing disabling injury) containable by a cleanup crew with potential for systemic toxicity, or capable of producing flammable vapors, or causing internal tissue damage. The 5-micron surgical masks, gloves, and goggles are not sufficient to protect the crew. Either quick don masks or SEBS required by all crewmembers. Only the cleanup crew will be required to wear gloves. Example: Acetonitryle.

TABLE 5-I.- HAZARDOUS SPILL LEVELS (cont)

Color/ Level	State	Flammability	Systemic/ internal damage	Irritancy	Criticality level	Summary of hazard level
Yellow 2	Either a solid or nonvolatile liquid which can be contained by a cleanup crew and disposed of. Crew protected by 5-micron surgical masks, gloves, and goggles.	May be capable of producing flammable solids or liquids (but not vapors) in sufficient quantity to produce a hazard.	None	Moderate to severe irritation with potential for long-term crew performance decrement (for eye-only hazards, there must be a risk of permanent eye damage). Note: Will require therapy.	Catastrophic	Catastrophic hazard (capable of causing disabling injury) but containable by a cleanup crew. No systemic toxicity concerns or tissue damage (other than eye); 5-micron surgical masks, goggles, and gloves will protect the crew. Quick don masks and SEBS not required. Since the substance is a severe irritant or could cause eye damage, the crew must wear surgical masks, goggles, and gloves. No provision for severe skin irritation or absorption. Example: Sodium hydroxide with very high pH (>12).
Blue 1	May or may not be containable. Crew protected by surgical masks and goggles.	Very low flammability potential. Substance has a high flash point and low vapor pressure.	Minimal effects. No potential for lasting internal tissue damage or injury.	Slight to moderate irritation that lasts more than 30 minutes. If an eye-only hazard, can affect visual acuity for more than 30 minutes. Note: Will require therapy.	Critical	Critical hazard (capable of causing nondisabling injury) and may or may not be containable by a cleanup crew. Crew must be protected by surgical masks and goggles. With level 1 hazards, it is assumed that the crew needs therapy if exposed. Therefore, all crewmembers in the area must wear protective gear to avoid contact. Example: Solutions like 15 % sodium chloride.
Green 0	May or may not be containable.	None	None	Slight irritation that lasts less than 30 minutes and does not require therapy. Effects resolved within 30 minutes without therapy.	None	Not a health or fire hazard. May or may not be containable. If not, report to MCC. Example: Silicon oil or weak hypertonic solutions.

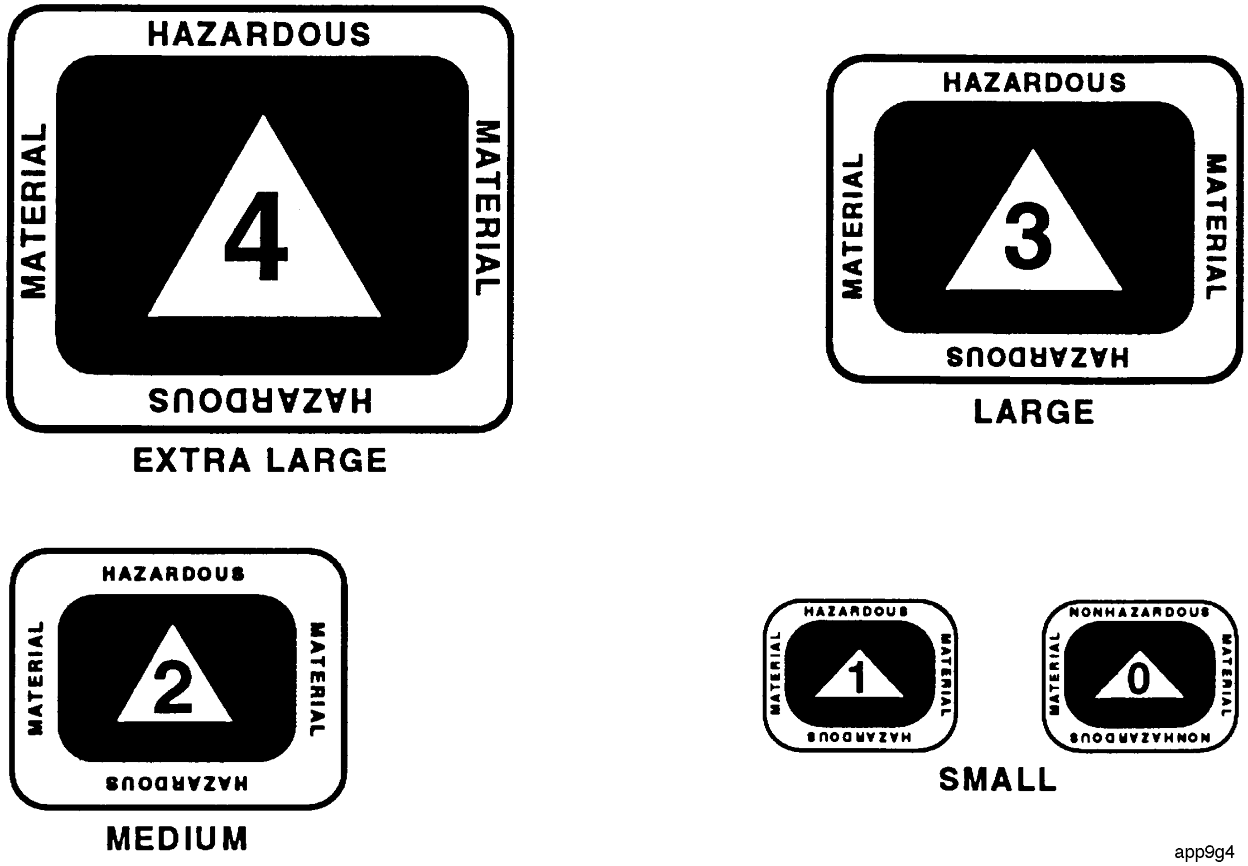

Figure 5-3.- Hazardous decal examples (actual sizes shown).

5.7 Transfer Requirements

Factors such as package geometry, size, mass, transfer clearance envelope, and positioning requirements should be considered before transporting replacement modules or servicing equipment from launch stowage locations to the servicing worksite. Transfer aids shall not pose a safety hazard to crewmembers; no other specific criteria exist for the design of these payload-peculiar aids. Items such as large and small trash bags, specialized bags, and tool caddies are available from the SSP as an optional service and may be used to transfer equipment of various sizes.

5.8 Atmosphere

Customer-provided habitable modules must ensure a safe and habitable atmosphere compatible with that of the orbiter, and must establish acceptable preflight offgassing levels as described in NSTS 1700.7B.

The payload system shall provide for adequate atmospheric interchange with the orbiter and proper circulation and temperature/humidity conditioning within the payload. The orbiter environmental control and life support system (ECLSS) will provide carbon dioxide removal, oxygen replenishment, and total pressure control.

The payload shall have a scrubber and filtration system to adequately cleanse the expected payload atmosphere. Trace gas contaminant levels shall not exceed concentrations specified for spacecraft in Spacecraft Maximum Allowable Contaminant Concentrations for Space Transportation Systems Applications, JSC 20584.

Any consumables required for repressurization after venting of the module atmosphere shall also be supplied by the customer. Rehabitation of a customer-supplied module may be permitted by the SSP, following problem resolution, purging, repressurization, and reverification of the module atmosphere. Reverification shall be accomplished as defined in NSTS 1700.7B.

5.9 Habitability

General guidelines for radiation levels, thermal stability, visibility, acoustics, and vibration are described in this subsection.

5.9.1 Ionizing Radiation

Table 5-II defines dose limits which may not be exceeded. The SSP shall provide dosimeters for measuring radiation exposure. Space Shuttle flights are nominally constrained to 30-day exposure limits, which are conservatively set to preclude any mission impact. NASA-STD-3000 describes the space radiation environment and example design solutions.

TABLE 5-II.- IONIZING RADIATION EXPOSURE LIMITS FROM SPACE FLIGHT

Constraints in rem*	Depth (5 cm)	Eye (0.3 cm)	Skin (0.01 cm)
30 days	25 rem	100 rem	150 rem
Annual	50 rem	200 rem	300 rem
Career	100-400** rem	400 rem	600 rem

*rem = Radiation absorbed dose, in rads, multiplied by a quality factor, Q, to account for the relative biological effectiveness of different types of radiation. For planning purposes, Q = 1.2.

**The career depth dose equivalent limit is based upon a maximum 3% lifetime risk of career mortality. The total dose equivalent yielding this risk depends on sex and age at start of exposure. The career dose equivalent is approximately equal to: Male - 200 + 7.5 (age minus 30) rem, up to 400 rem maximum. Female - 200 + 7.5 (age minus 38) rem, up to 400 rem maximum.

Note: Space Shuttle crew radiation exposure limits were recommended to NASA by the National Council on Radiation Protection and Measurement in 1987 and are expected to be legally adopted as the supplementary standard for compliance with Supplementary Standards, 29 CFR 1960.18. Space Shuttle flights are nominally constrained to 30-day exposure limits, which are conservatively set to preclude any mission impact.

5.9.2 Nonionizing Radiation

RF protection guidelines published by the American National Standards Institute (ANSI) contain criteria adopted by NASA to ensure safe RF/microwave exposure limits for the IVA crew. Figure 5-4 illustrates these limits for RF electromagnetic fields.

Equipment tolerance of nonionizing radiation is a more limiting factor for payload designers than crew tolerance. ICD 2-19001 defines allowable limits of intentional and unintentional electric field strength in the orbiter crew compartment.

5.9.3 Thermal

Crew protection from exposure to high or low surface temperature extremes is required in accordance with NSTS 1700.7B.

For habitable modules, the instrumentation necessary for monitoring module temperature, partial pressure of CO_2, relative humidity or dew point, and cabin fan flow rate parameters shall be provided by the customer.

5.9.4 Visibility and Lighting

Lighting requirements to ensure sufficient illumination and provide redundancy consistent with emergency egress are specified in NSTS 1700.7B.

NASA-STD-3000 provides design guidelines for illumination levels, light distribution, glare, brightness, dark adaptation, etc.

5.9.5 Acoustics

Noise generation shall be controlled so that acoustic energy will not injure personnel, interfere with communications, induce fatigue, or contribute to degradation of overall man/ machine effectiveness.

Maximum noise levels in customer-supplied habitable modules during manned operations shall not exceed the limits defined in NSTS 1700.7B and depicted in Figure 5-5.

Individual payload elements in the orbiter middeck acoustic environment shall not exceed limits defined in NSTS 21000-IDD-MDK.

5.9.6 Vibration

Vibration shall be controlled to guard against crew injury and interference with task performance. Equipment shall be designed and mounted to minimize vibration at crew stations, and shall be compatible with all orbiter environments.

5.10 Crew Command, Control, and Display

Indicator lights shall conform to MIL-STD-1472D. Controls should be designed for barehanded operations unless gloved operations are specifically designated as a requirement. Controls should be designed to minimize susceptibility to accidental movement. Design of critical controls whose inadvertent operation could cause damage to equipment or personnel requires particular attention.

NASA-STD-3000 provides design guidance for knobs, switches, input devices, and display systems.

5.11 Access Doors and Drawers

Doors and drawers providing IVA access should incorporate integral locking and unlocking mechanisms suitable for one-handed operation, a hold-open mechanism, a handhold for crewmember position control when opening and closing, and some visual means for verifying proper closing and latching.

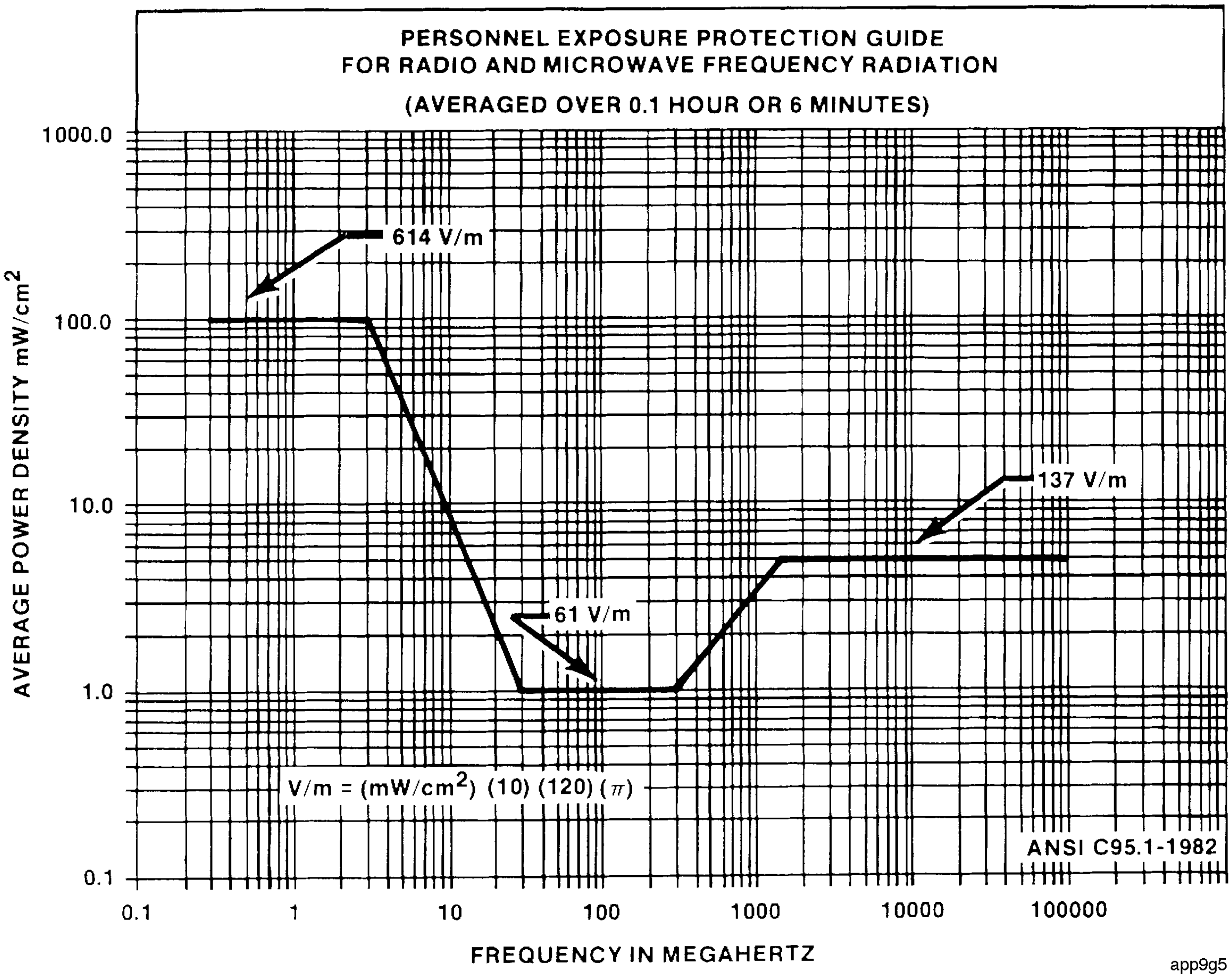

Figure 5-4.- IVA crew nonionizing radiation limits from space flight.

5.12 Windows

Windows shall be provided in the customer-supplied crew module only when necessary for essential mission operations. Consult NSTS 1700.7B. Design verification shall be in accordance with Payload Verification Requirements, NSTS 14046.

5.13 Pressure Hull

Pressure hull design for customer-supplied habitable modules shall comply with requirements defined in NSTS 1700.7B, and structural verification shall be in accordance with NSTS 14046.

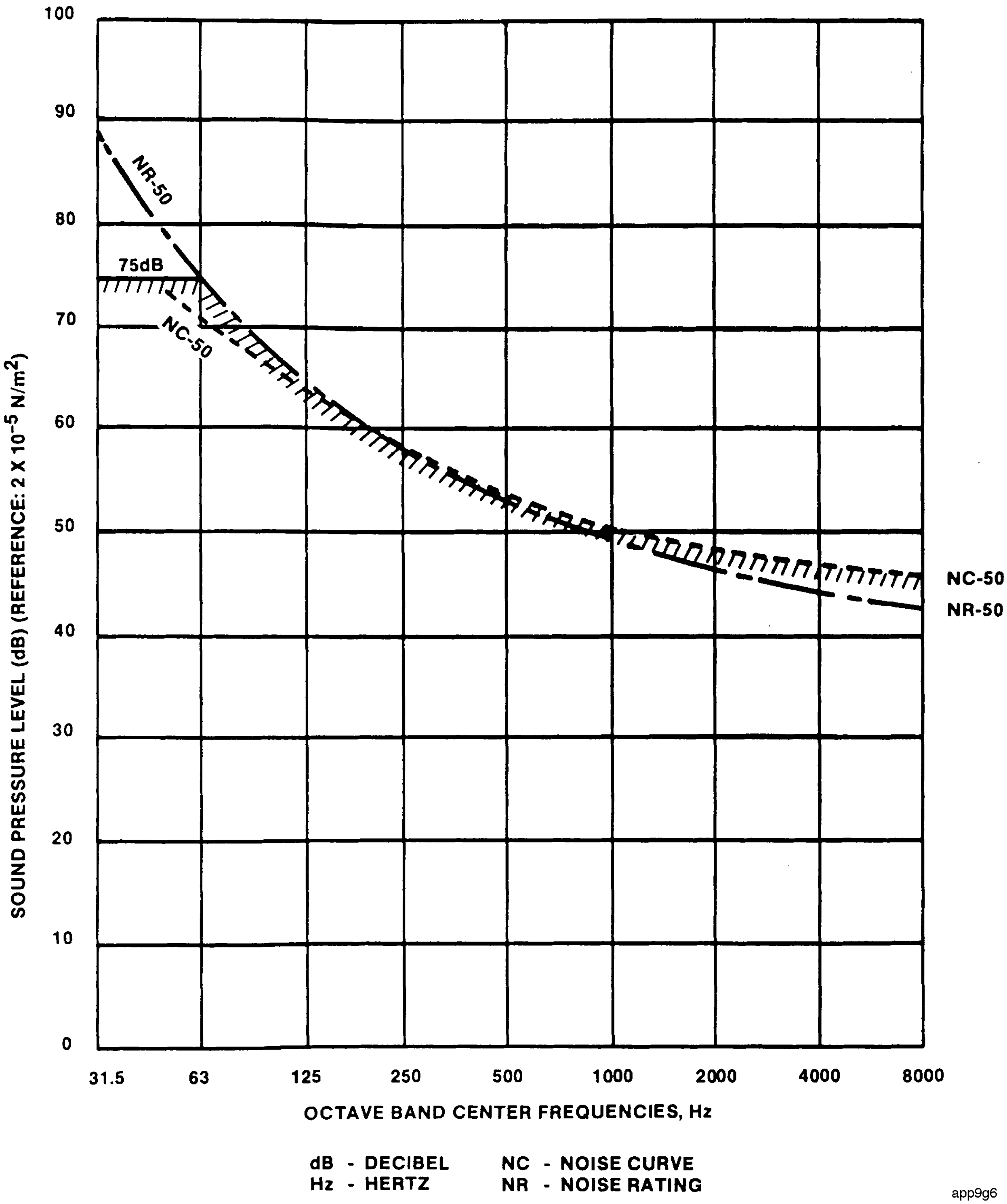

Figure 5-5.- Maximum acoustic noise levels inside the module.

Inflight Maintenance Provisions

6

6.1 Intravehicular Activity Inflight Maintenance Definitions

a. IFM

For the purposes of this appendix, IFM is defined as on-orbit hardware maintenance or repair actions conducted by the crew within the confines of the pressurized vessel or payload module to keep the payload operable or return it to operability. It normally involves removal of payload panels, mating and demating of electrical connectors, or replacement of LRU's.

IFM is often accomplished after a malfunction procedure has failed to correct an anomaly. An IFM procedure involves maintenance or repair of hardware, such as wire repair and searching for and repairing leaks.

IFM specifically excludes software changes. No real time changes to software controlling hazardous functions are permitted. Limited changes may be made to software that does not control hazardous functions after assessment of the impact on crew procedures and approval by the Space Shuttle commander and Mission Control Center-Houston (MCC-H) flight director.

b. Scheduled Maintenance

Scheduled maintenance includes routine maintenance conducted at specific, preflight-determined intervals and scheduled in the crew activity plan. It is normally scheduled on the basis of historical operational data, mean time between failures (MTBF), and other ground or on-orbit operational maintenance data. Scheduled maintenance is normally planned using hardware operational hours or calendar days.

c. Unscheduled Maintenance

Unscheduled maintenance is conducted to return failed hardware to an operational state. Unscheduled maintenance may be required because of unknown or unforeseen events.

d. Preventive Maintenance

Preventive maintenance is a form of scheduled or unscheduled maintenance conducted on operational equipment to extend its operating life or preclude its failure (e.g., on-orbit replacement of operational replacement units prior to failure, based on existing failure data).

- Cleaning

  Cleaning is preventive maintenance conducted to prevent accumulation of harmful bacteria, toxic gases, debris, corrosion, or other material that may cause failure of equipment or constitute a threat to safety or health. Examples include on-orbit vacuum cleaning of filters protecting air-cooled avionics components, removal of toxic solids from payload experiments to prevent contaminating cabin atmosphere, microbiological "wipe down" of surfaces and air ducts, and waste collection and stowage to prevent bacterial buildup.

- Servicing

  Servicing is preventive maintenance conducted to replace consumable fluids, gases, or nonconsumable high-time components which might be expected to fail based on previous experience with the MTBF for a particular piece of hardware. Lithium hydroxide cartridge replacement, gaseous oxygen refurbishment, replacement of fluids in payload experiments, and replacement of components within payload experiments are examples of payload IFM servicing. Replacement of an entire payload experiment with another experiment, either identical or different in design, or replacement of its components (e.g., fluids) after the experiment has completed its preplanned, normal operation is considered servicing (scheduled maintenance). Replacement of a payload experiment or its components before planned, normal operations are complete is also considered servicing (unscheduled maintenance).

e. Test and Measurement

Test and measurement includes scheduled or unscheduled maintenance conducted to examine the operational state of hardware and determine if further maintenance is required (e.g., testing an electrical circuit using a multimeter, oscilloscope, or other appropriate testing device to check operational status).

6.2 Intravehicular Activity Inflight Maintenance Categories

a. Preflight developed IFM - Scheduled or unscheduled maintenance tasks developed, written, assessed for safety implications, and trained for prior to launch and either conducted pending the assumed failure (unscheduled maintenance) or in the case of scheduled maintenance (e.g., filter cleaning), incorporated preflight into the mission timeline.

b. Real time developed IFM - Unscheduled maintenance tasks or procedures which are developed, written, and reviewed by MCC-H and customer personnel during on-orbit operations.

6.3 Rationale

It is important to understand the definitions of categories and types of maintenance because constraints on IFM activities are based on these definitions. For example, scheduled IFM is planned, approved, and timelined preflight and usually accomplished without real time consultation with the MCC-H. Exceptions include maintenance activities related to crew safety, such as servicing of toxic wastes. Unscheduled IFM is always reviewed in real time by the MCC-H to determine Space Shuttle interfaces and/or crew safety impacts, and approved or disapproved by the MCC-H flight director and Space Shuttle commander.

These definitions of types of maintenance also differentiate maintenance from normal operations. For example, normal payload operations may be involved in routine output of a product, such as crystals or fluid drops. Maintenance activities ensure its continued production or restore production capability. Examples are fluid changes, replacement of high-time components which may be expected to fail (scheduled servicing), and replacement of experiments following unanticipated failure (unscheduled maintenance). Each may require different air/ground coordination processes, depending on the purpose of each experiment and the safety impact involved. Coordination processes are defined and negotiated preflight, and included in PIP Annex 3.

NOTE: The payload customer is urged to consult SSP personnel well in advance of the flight to assist in anticipating hardware anomalies and developing IFM techniques and procedures for repairing failed payload equipment. Dependence on real time development of IFM procedures entails greater risk for potential loss of valuable experiment/ payload data or samples, and involves additional operational constraints as described in the following paragraphs.

6.4 Inflight Maintenance Guidelines and Constraints

SSP guidelines for small and middeck type payloads are to conduct IFM only as identified, reviewed, certified safe, and trained for preflight. Any subsequent reference to real time developed IFM applies to systems where failure represents a substantial loss of mission objectives.

Specific constraints which apply to performance of IFM are as follows:

a. Real time developed IFM procedures and procedures with orbiter or safety impacts shall be initiated only with the approval of the MCC-H flight director, Space Shuttle commander, and payload representative. When communication with the MCC-H is not possible and the Space Shuttle commander determines that the situation is critical, IFM may be initiated during a loss-of-signal period to ensure the integrity of the orbiter and/or safety of the crew.

   Preflight-developed payload IFM also requires real time coordination and approval by the Space Shuttle commander and MCC-H flight director unless it is scheduled in the flight plan. IFM procedures are written preflight assuming particular hardware configurations, interrelationships, and hardware failure sequences. To ensure that the conditions for which a particular IFM procedure was written actually exist during on-orbit operations, the procedure is reviewed in real time by the MCC-H. IFM procedures may involve removal of panels, electrical connectors, or other critical components or hardware. Safety dictates review and approval of these procedures by the MCC-H flight director and Space Shuttle commander during real time operations to assess their impact on the current on-orbit situation.

b. IFM procedures on payload experiments with a potential for toxic hazard require MCC-H flight director and Space Shuttle commander concurrence prior to initiation. Protective equipment may be required. Payload equipment that represents a toxic hazard will be identified in the flight rules.

6.5 Standard Inflight Maintenance Provisions

Space Shuttle IFM provisions and basic orbiter IFM equipment are baselined for each Shuttle mission. This standard SSP accommodation satisfies the requirement to provide for contingency orbiter maintenance and repair and for ground support of these activities.

6.5.1 Orbiter Tools

The SSP provides a variety of IFM tools and equipment to enhance orbiter maintenance and repair capabilities. Tools are stowed in the orbiter middeck. IFM tools consist of hand tools (Figures 6-1 through 6-3) and electrical tools and equipment. Descriptions of the electrical instruments and summaries of their applications are provided.

a. Breakout box

   The IFM breakout box (Figure 6-4) is a general purpose unit that provides 3.5 to 28 Vdc, 0.5 to 10 amperes (A) power to any onboard system or hardware. It provides fused protection for the interfacing system, and can supply power to more than one piece of hardware at a time (subject to total orbiter power limitation). The breakout box may be used to:

   1. Standardize IFM interfaces with orbiter hardware when providing an alternate source of power

   2. Provide fused protection to orbiter wiring and hardware when applying contingency power

   3. Provide a variable power source for hardware requiring 3.5 to 28 Vdc

      The IFM breakout box has been manifested on the Shuttle since STS-51F, and has been used during on-orbit operations to power a camera with 14 Vdc after its batteries and spares were drained. Other IFM procedures utilize the breakout box, multimeter, and pin kit to power failed components.

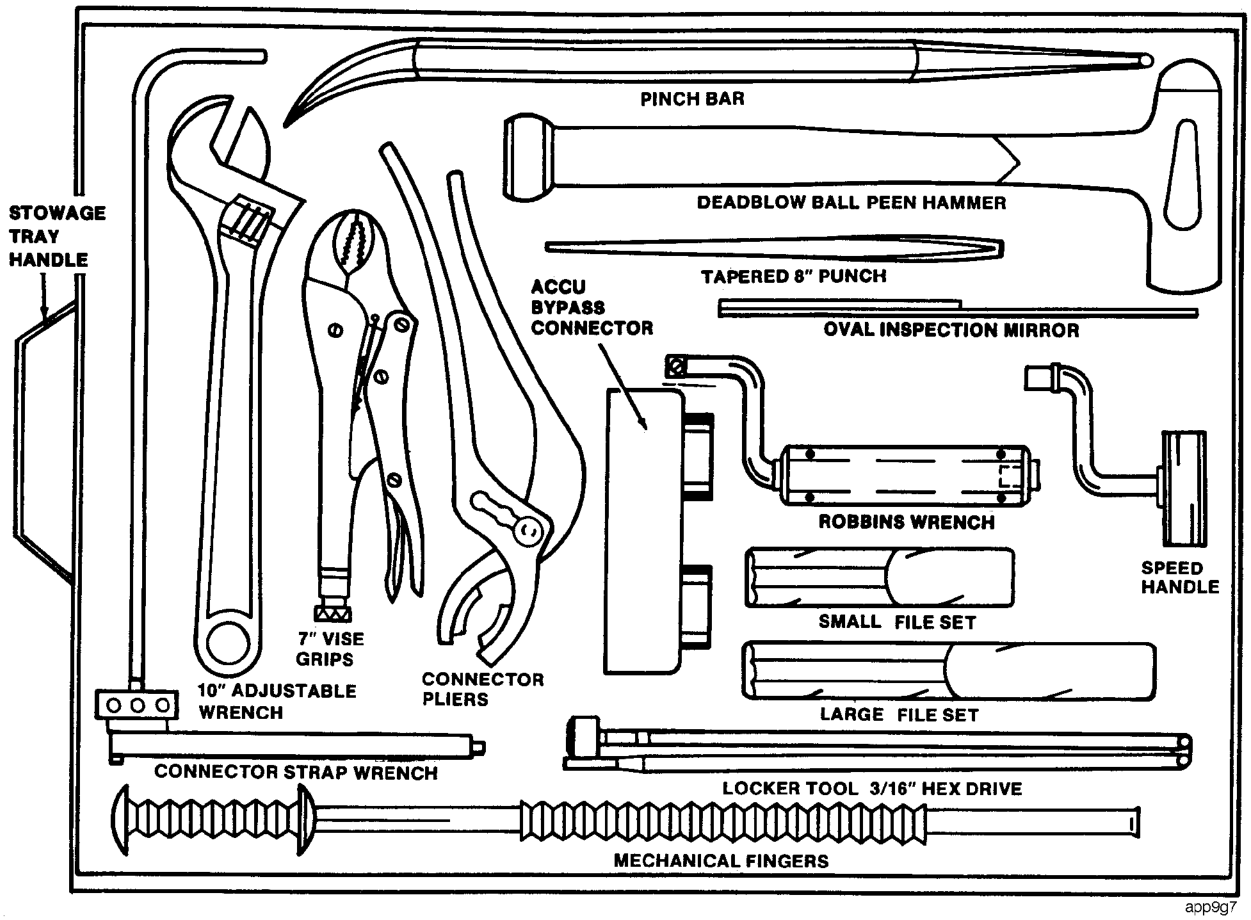

Figure 6-1.- Tray 2, IFM tools (typical packaging).

b. Power cable

A 24-foot power cable is used to mate the IFM breakout box to a dc utility outlet. Pin/socket test jumper leads are provided in lengths from 5 to 24 inches, and in sizes from 22 to 12 gauge (with length and size dependent on particular requirements). A pin/socket test jumper lead is attached to the output end of the IFM breakout box, and from there to the connector associated with a failed component. Two IFM breakout boxes and power cables are stowed with the orbiter IFM tools.

c. Multimeter

The multimeter (Figure 6-5) (Fluke digital, model #87) is used to test electrical output or resistance during troubleshooting activity. It is also used to set variable voltage levels on the IFM breakout box through interfacing sockets designed to mate with the multimeter test leads. When connected, the multimeter voltages are displayed as the operator rotates a potentiometer located on the box, thereby setting the output to the desired voltage (3.5 to 28 Vdc).

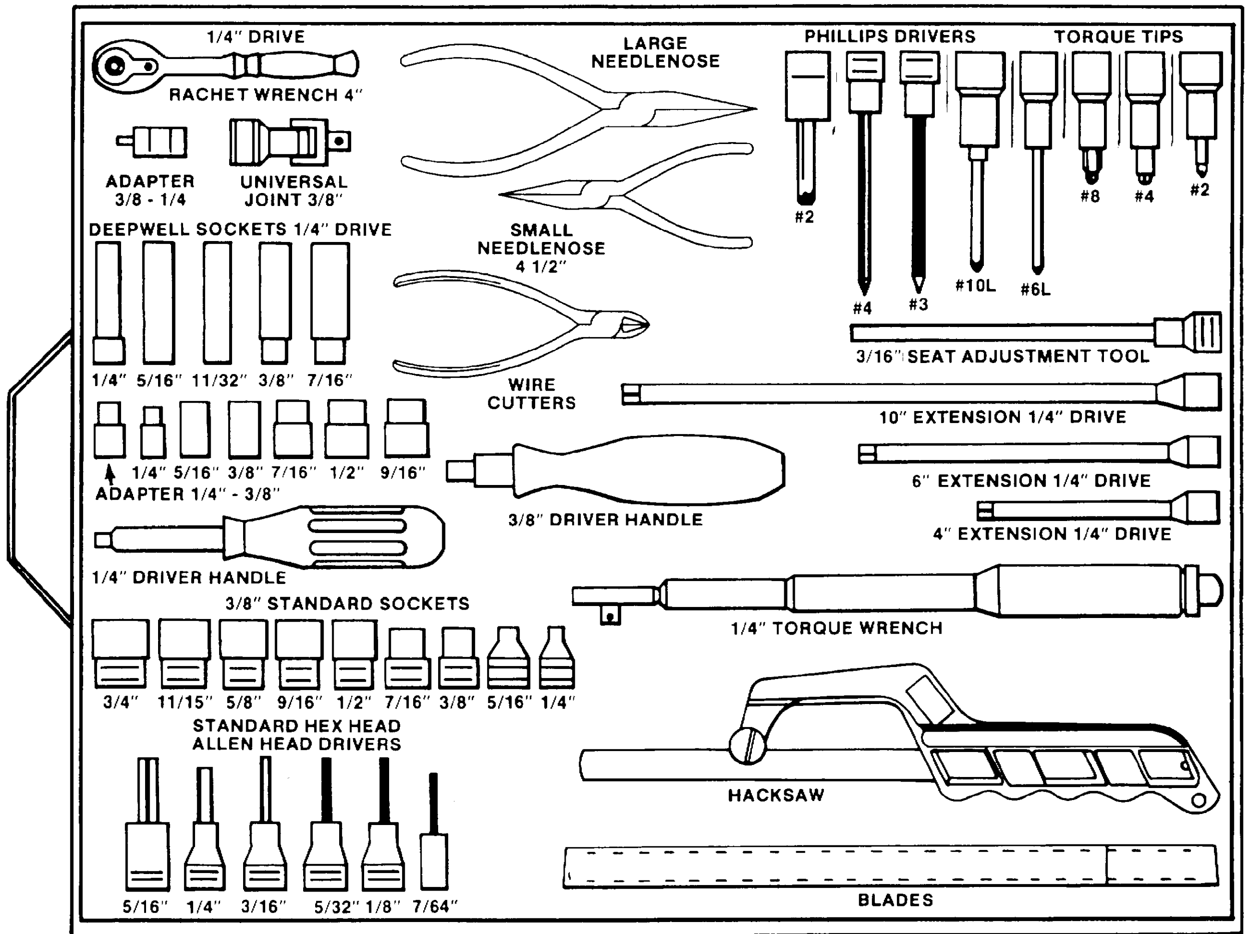

Figure 6-2.- Tray 3, IFM tools (typical packaging).

d. IFM pin kit

The IFM pin kit (Figure 6-6), in addition to its use with the IFM breakout box, is a multipurpose electrical repair kit containing spare wire and fuses, test jumper leads, alligator clips, multimeter adaptors, wire stripper, crimper, etc. It has been manifested aboard the shuttle since STS-2, and used on several flights to effect contingency repairs.

6.5.2 Spacelab Tools

On Spacelab module missions, a separate IFM tool kit is carried in the workbench rack. Spacelab tools (Figures 6-10 through 6-15) enhance and duplicate some of the tools found in orbiter stowage. These tools are available for customer-provided modules as negotiated with the SSP.

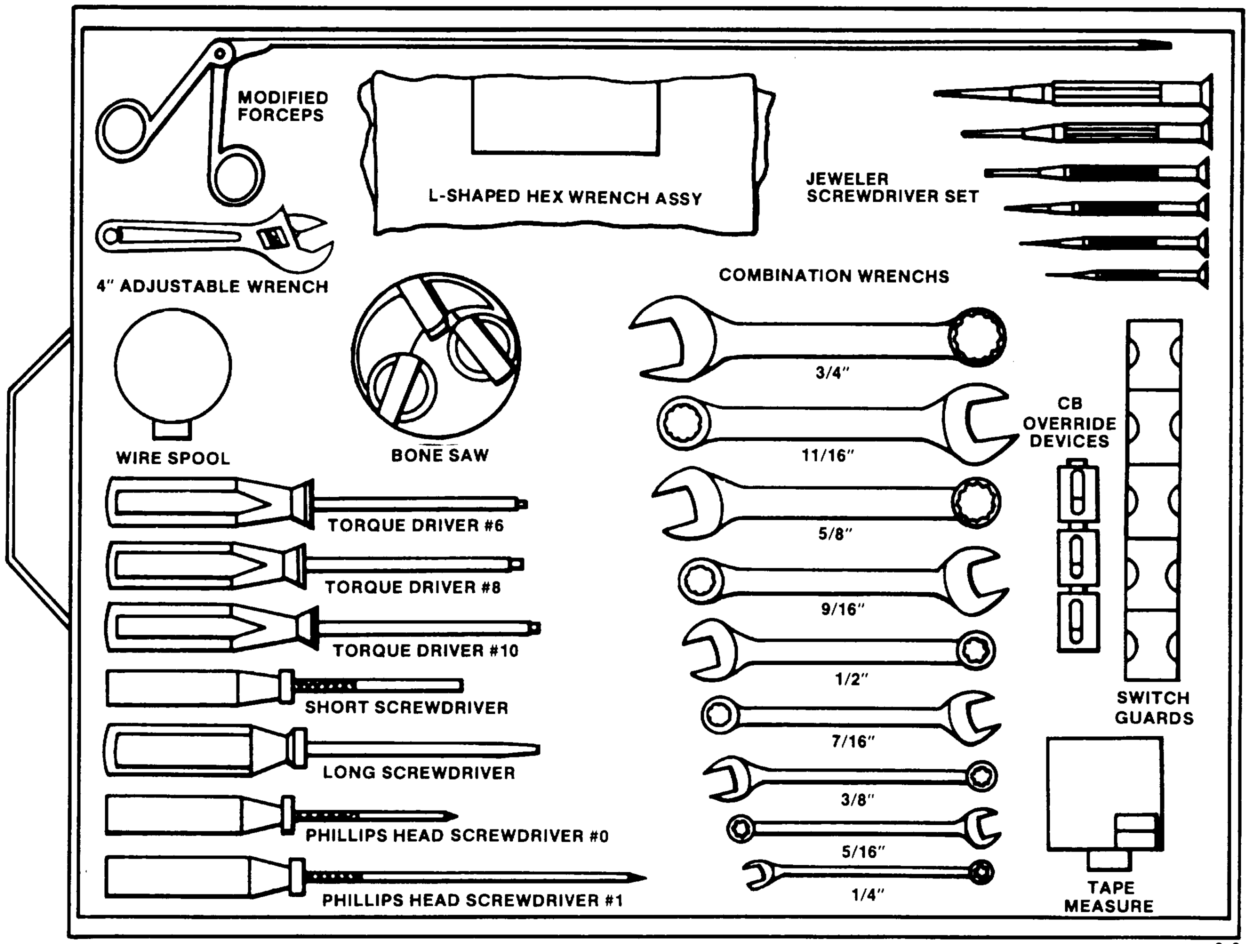

Figure 6-3.- Tray 4, IFM tools (typical packaging).

6.5.3 Customer-Provided Tools, Equipment, and Stowage

To minimize cost and simplify crew training and payload integration, customers are encouraged to use existing flight-certified tools described above whenever possible. The payload customer is not charged for refurbishment of items used in flight that will be returned to the SSP inventory.

Occasionally, payload-unique tools are required for maintenance of payload experiments. Identification, coordination, provisioning, and stowage of special tools is the responsibility of the payload customer. Customer-provided tools and equipment must meet the requirements listed in this appendix and those specified in NSTS 1700.7B. Guidelines in NASA-STD-3000 should also be considered. The customer should mount IFM tools at IFM worksites on payload equipment and stow tools within the payload volume. A charge will be made for any orbiter stowage of customer-provided IFM tools. The requirement for this service must be negotiated in the PIP.

A vacuum cleaner assembly (Figure 6-7) and a contingency hose and cable kit (Figure 6-8) are available. Typical tool assembly stowage is shown in Figure 6-9 along with additional items (Velcro kit, rolls of pressure tape, etc.).

Figure 6-4.- IFM breakout box.

6.6 Nonstandard Inflight Maintenance Provisions

Optional services provided to the individual customer are defined in the PIP.

6.6.1 Inflight Maintenance Preflight and Real Time Support

As an optional service, the SSP IFM support team can provide preflight assistance in anticipating anomalies and developing IFM procedures to repair or maintain payload equipment. The payload customer is urged to take advantage of this optional service to ensure maximum payload and mission success.

The SSP IFM support team also assists in developing and coordinating implementation of IFM procedures to correct any orbiter anomalies that might occur during on-orbit operations. This team also assists SSP customers with real time development of IFM procedures for unanticipated payload/experiment hardware failures. IFM real time ground support during on-orbit operations is an optional SSP service. In all cases, IFM procedures developed in real time must be assessed for crew safety and orbiter impact/ damage, and approved by the MCC-H flight director and the Space Shuttle commander.

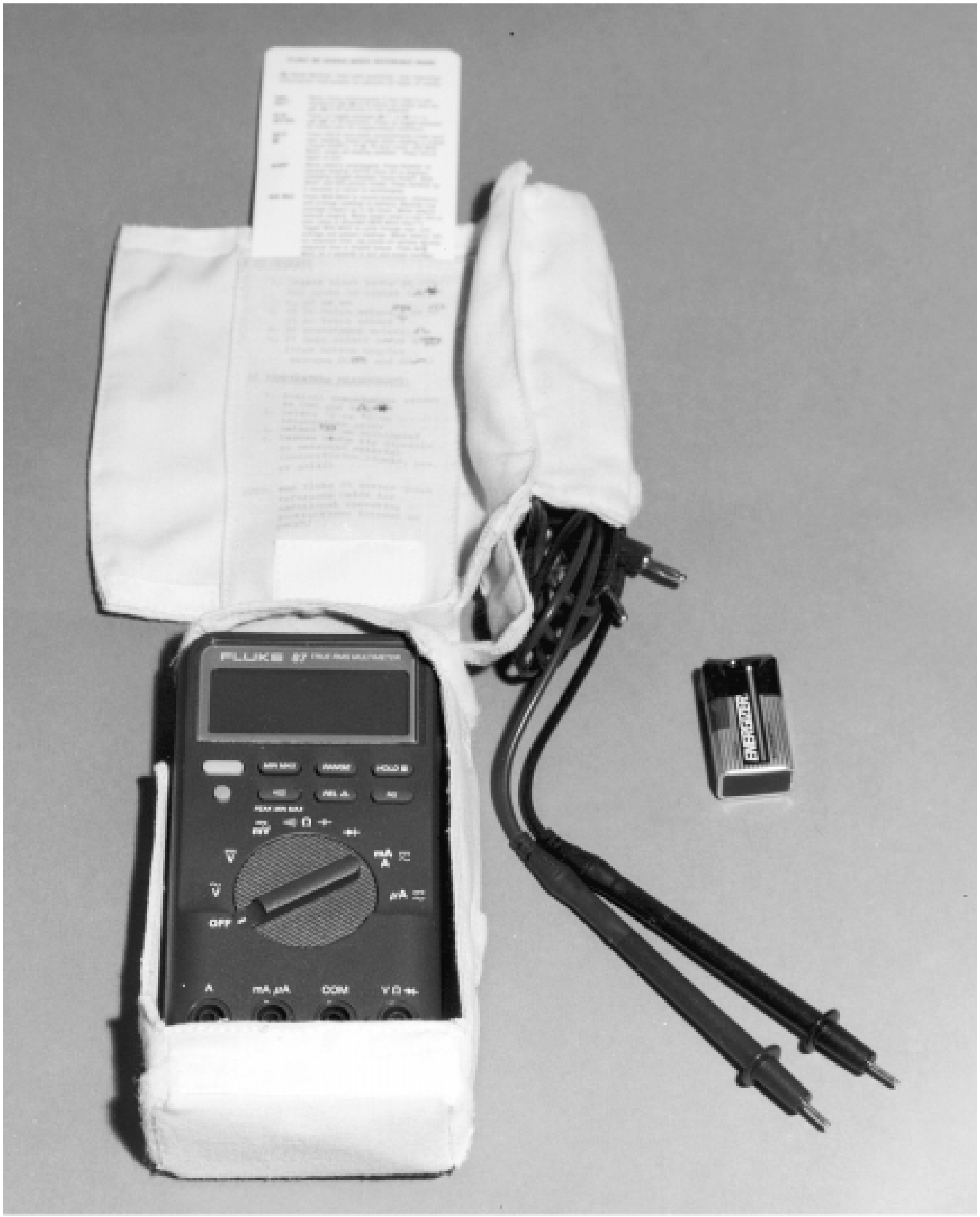

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Figure 6-5.- Digital multimeter.

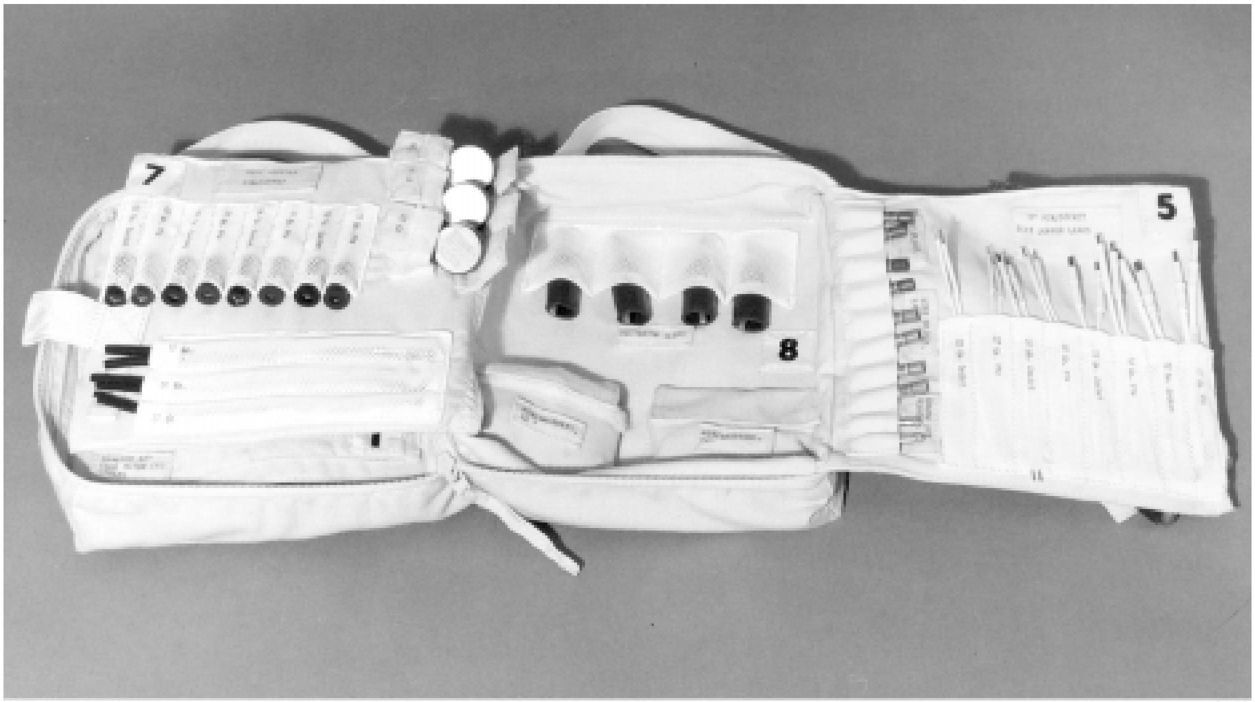

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Figure 6-6.- IFM pin kit (typical packaging).

6.6.2 Nonbaselined Tools and Equipment

The customer may request in the PIP use of certified items not baselined for that mission. These items are payload chargeable (as an optional service) based on weight and/or volume. The customer will not be charged for refurbishment of items used in flight that will be returned to the SSP inventory. Customer requirements for any SSP tools and equipment will be negotiated during the PIP development process.

6.6.3 Optional Service Inflight Maintenance Tools, Equipment, and Stowage

As previously described, IFM equipment may be provided by the customer or selected from the SSP inventory of payload chargeable items.

Customers may also request in the PIP that the SSP design, develop, build, and certify a special tool or piece of equipment as an optional service. Orbiter stowage space is limited, and the customer may be charged for stowage of payload IFM equipment as negotiated with the SSP.

6.7 Orbiter Interface Communications

All IFM requires constant and effective communication among all participants. In the case of preflight-defined IFM tasks, early communication and contact with appropriate personnel will be scheduled and performed, and lists of primary payload contacts provided to the customer. SSP IFM flight controllers staff a console full-time during real time on-orbit operations. Communication requirements for IFM coordination are defined in PIP Annex 3.

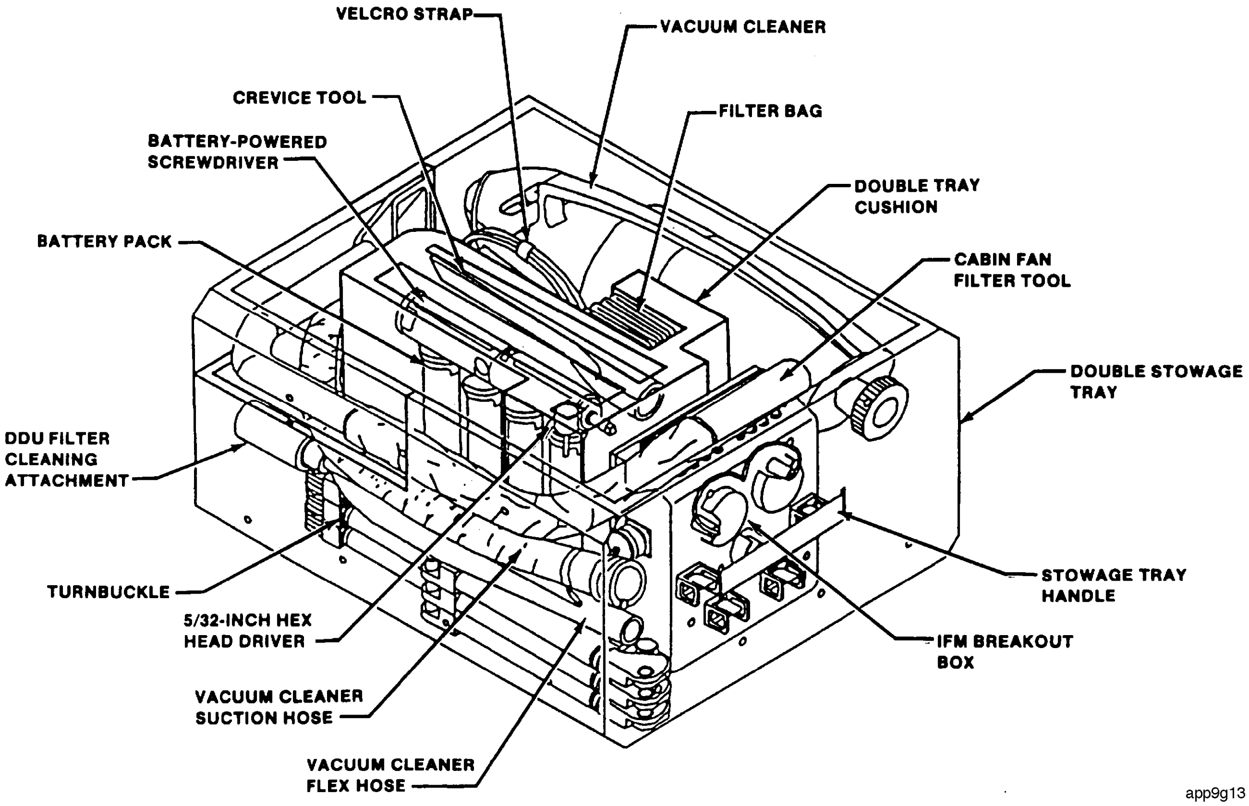


Figure 6-7.- Double tray vacuum cleaner assembly (typical packaging).

6.8 Orbiter Inflight Maintenance Analysis

Payload IFM tasks and procedures will be analyzed by the SSP to ensure that interfaces with Space Shuttle hardware do not adversely affect crew safety or orbiter systems. Similar analyses are conducted for handling toxic materials during proposed IFM activity. Safety analysis for payload-manifested IFM tools and equipment shall be documented in payload hazard reports. An evaluation of the IFM timeline and IFM configurations will be conducted by the SSP to ensure compatibility during normal and contingency operations. One-g test facilities provided by both the SSP and the customer support these activities.

6.9 Orbiter Inflight Maintenance Tool and Equipment Interface Review

The SSP is responsible for the location and configuration of orbiter IFM tools and equipment stowed in the middeck. Unique payload-related IFM tool and equipment requirements will be described in the PIP. IFM tools and equipment not manifested by the SSP which are required to accomplish payload IFM tasks are manifested and stowed by the customer, but are reviewed by the SSP for orbiter interface and safety.

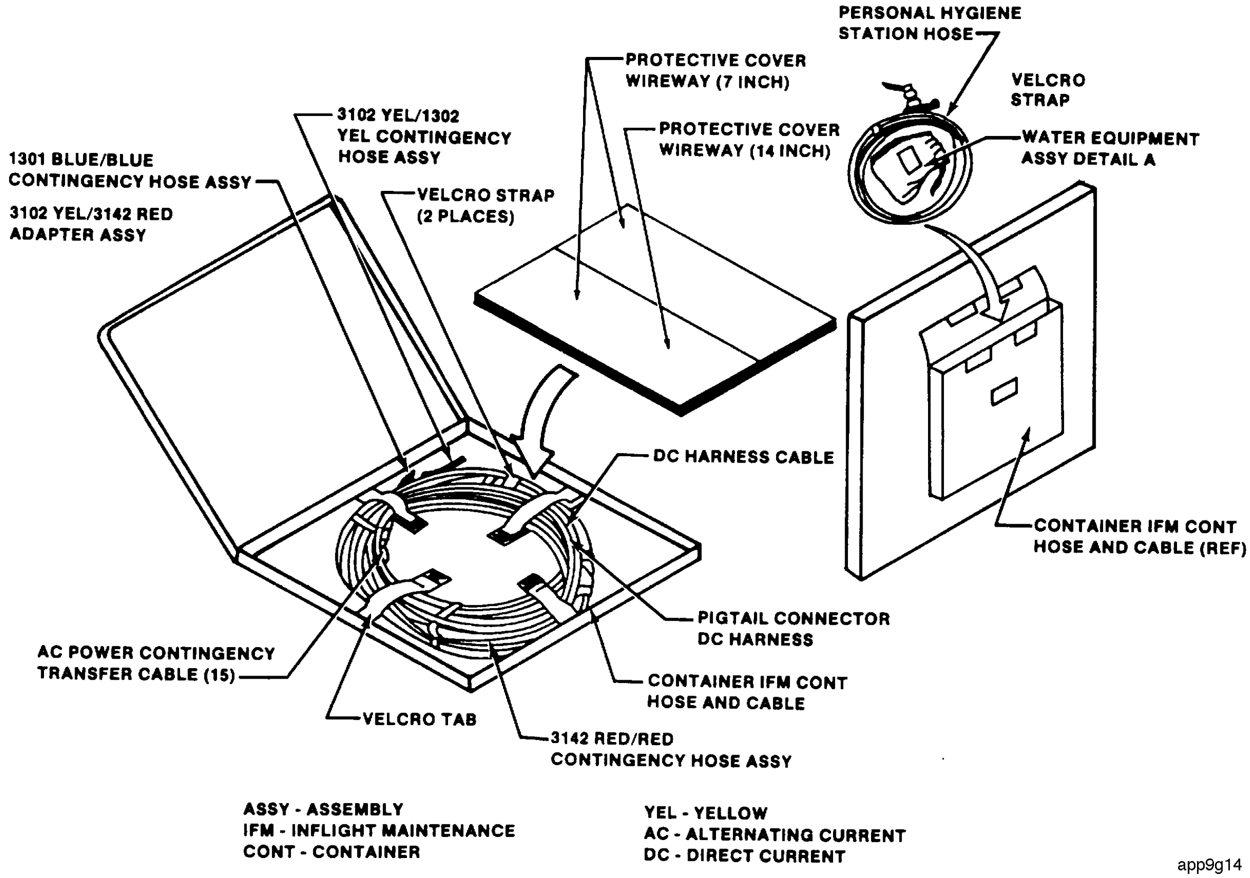


Figure 6-8.- IFM contingency hose and cable kit (typical packaging).

6.10 Inflight Maintenance Real Time Operational Performance Criteria

Preflight-defined unscheduled payload IFM procedures are reviewed by the MCC-H during real time operations to ensure that the conditions for which the procedures were written actually exist in real time. This MCC-H real time review will also ensure that the procedures do not have undesirable effects on Space Shuttle systems or crew safety. Approval of unscheduled payload IFM will be granted by the MCC-H flight director and Space Shuttle commander if these concerns are answered favorably.

If the MCC-H flight director or Space Shuttle commander determines that the conditions for which the payload IFM procedures were written do not exist in real time, the procedure will be disapproved and returned to the customer for further analysis and development.

Any payload IFM procedure with a Space Shuttle or crew safety impact automatically becomes a Space Shuttle IFM procedure, and is developed, written, and approved or disapproved by the MCC-H as if it were an orbiter IFM procedure, but in full coordination with the payload customer. IFM will not be performed without appropriate power down of affected payload systems to prevent hazard to crewmembers. Preflight-defined IFM shall be planned so that power down of Space Shuttle hardware is not required. Payloads and systems that will not be powered off during IFM activity are identified in PIP Annex 3.

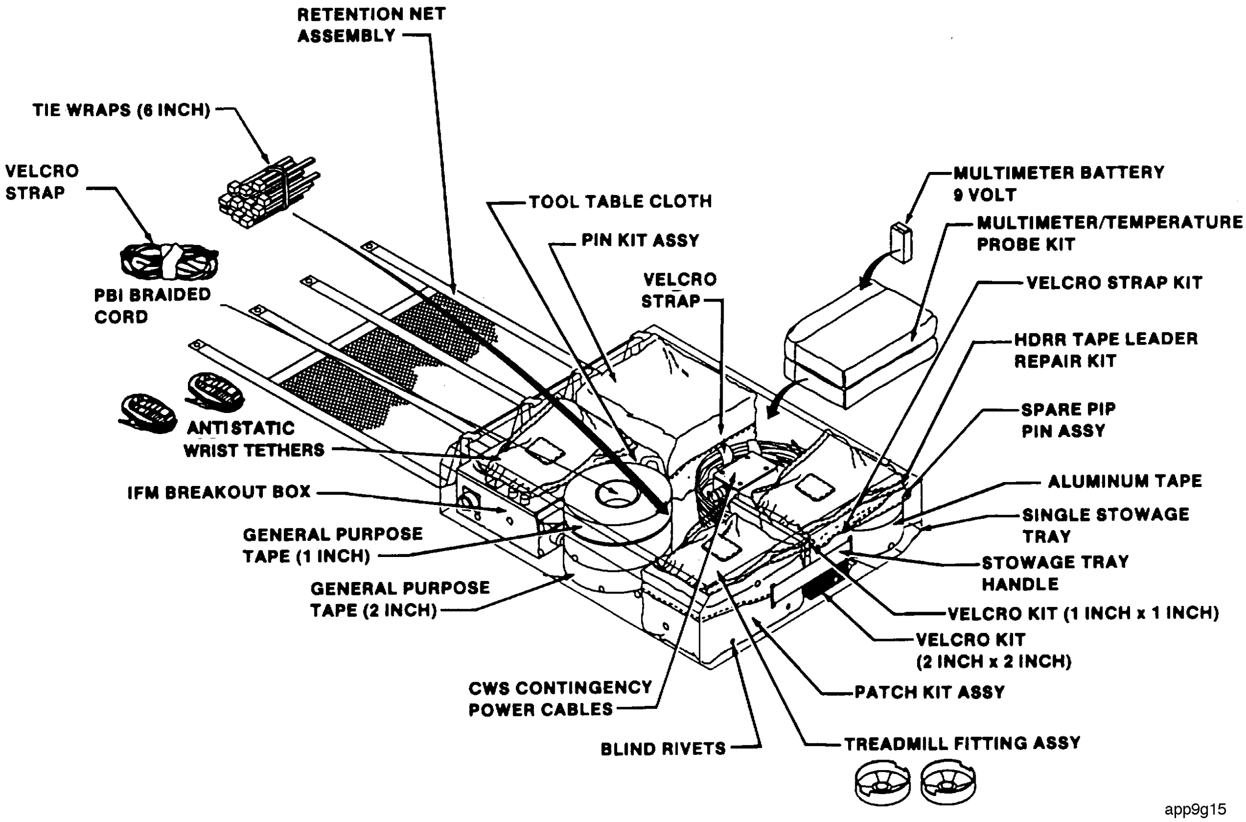


Figure 6-9.- IFM single tray assembly (typical packaging).

6.11 Inflight Maintenance Operational Timeline Considerations

Time required for a particular IFM task developed for real time on-orbit operations cannot be specified. Crew response to the task will be consistent with JSC 22359. For shared payloads, the SSP will also consider other mission objectives.

The IFM activity described in this appendix is normally based on each IFM scenario performed by two persons. Unscheduled maintenance on experiments with no Space Shuttle interface or crew safety impact will be performed by two crewmembers, one of whom will be a mission specialist. IFM on experiments with a Space Shuttle interface or crew safety impact is performed by Space Shuttle crewmembers (commander, pilot, mission specialist) only. Scheduled maintenance will be performed by the required number of crewmembers as determined and approved preflight.

6.12 Procedure Development/ Verification and Crew Training

The SSP is responsible for assessing mission-specific IFM techniques, developing integrated crew procedures, and conducting orbiter/ payload integrated crew training.

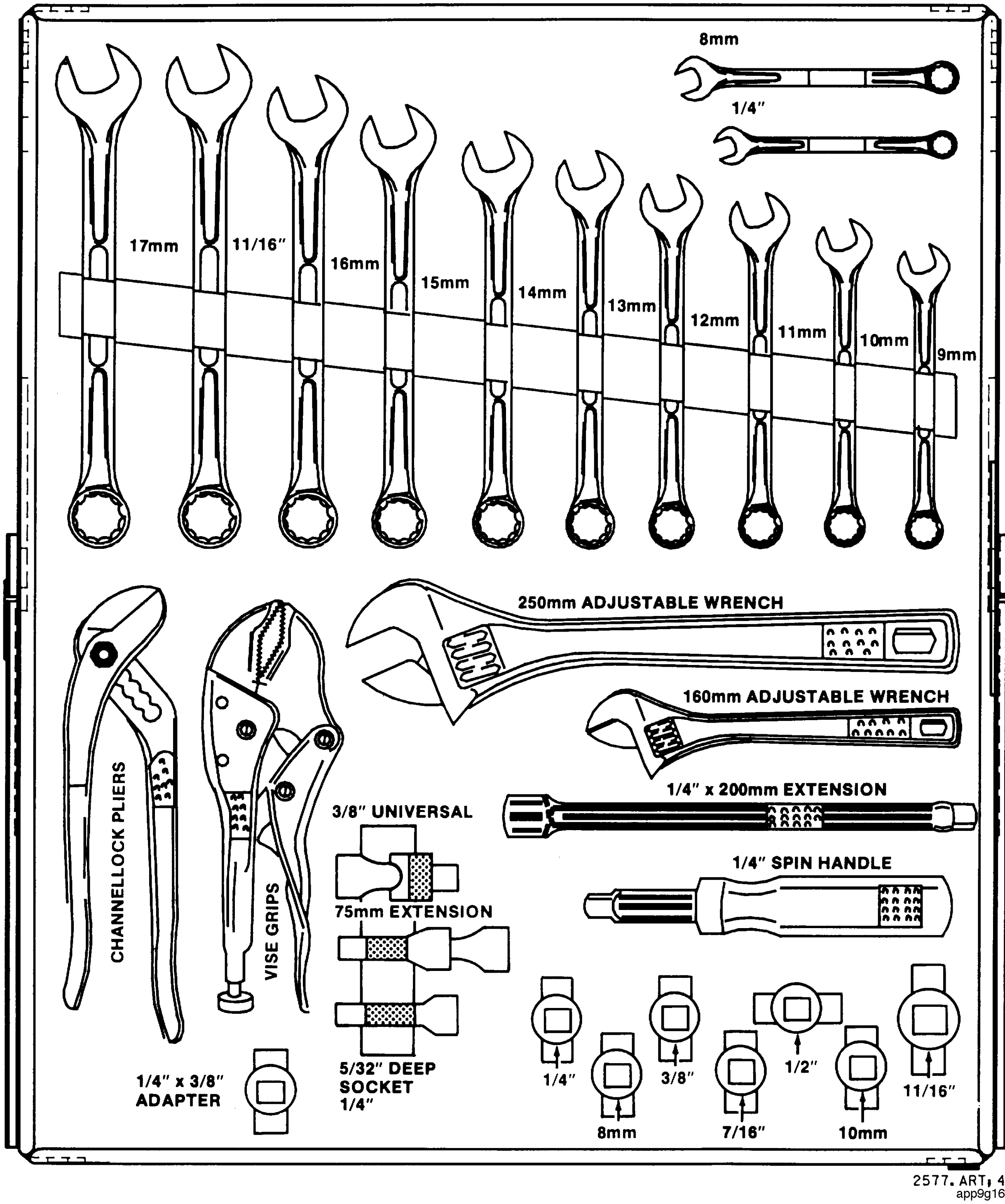
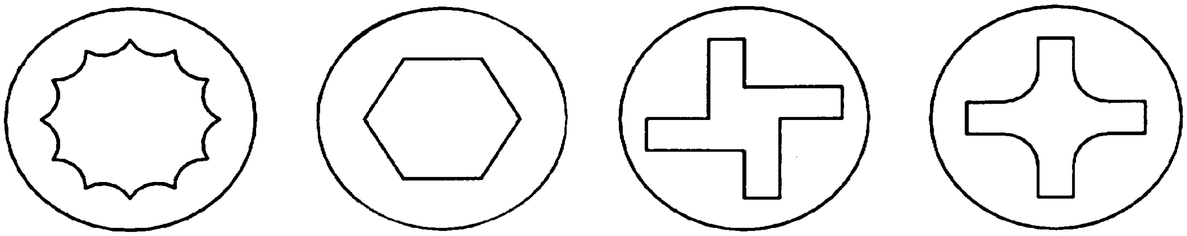


Figure 6-10.- Drawer 1, Spacelab tools (typical packaging).



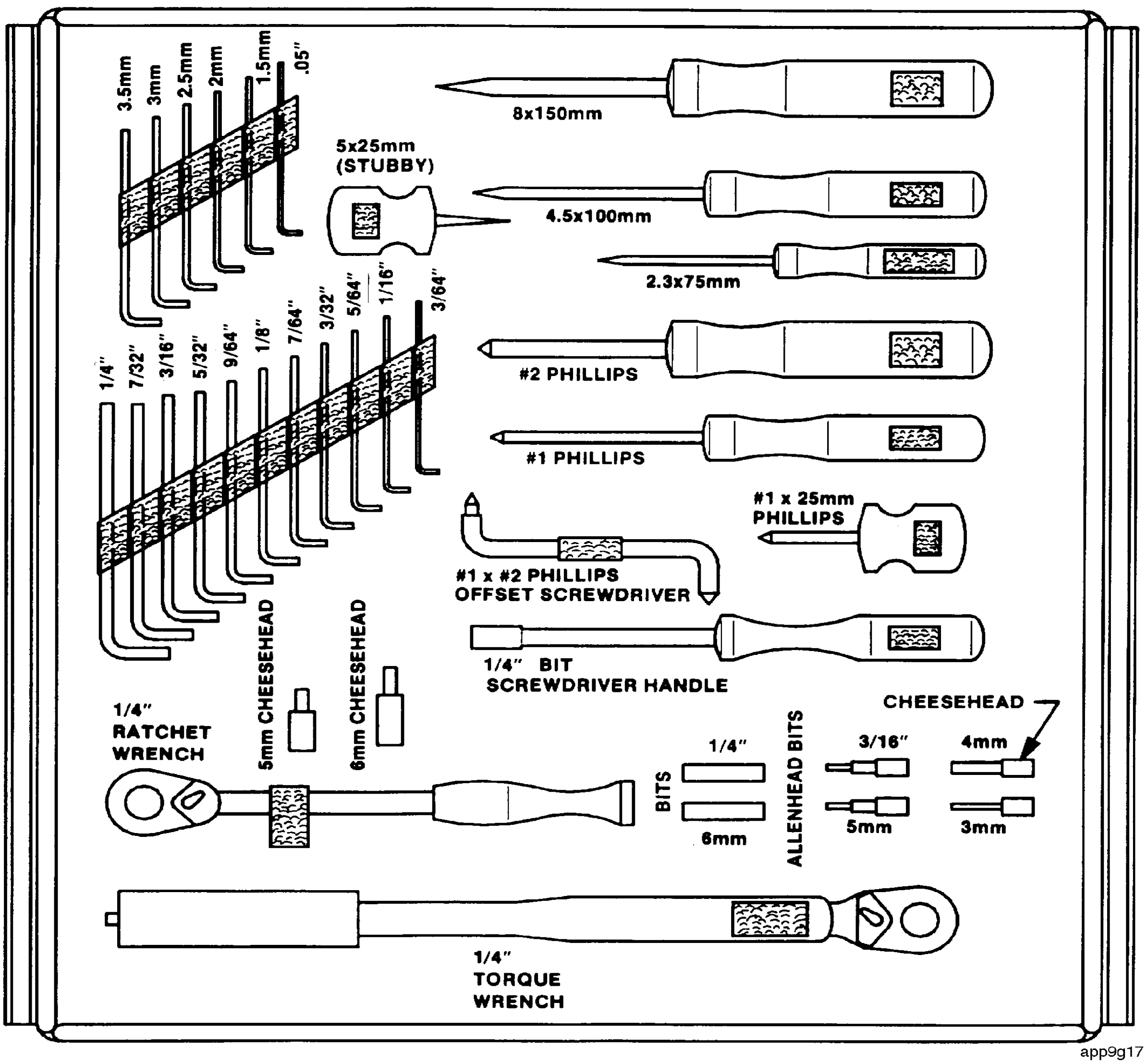


Figure 6-11.- Drawer 2, Spacelab tools (typical packaging).

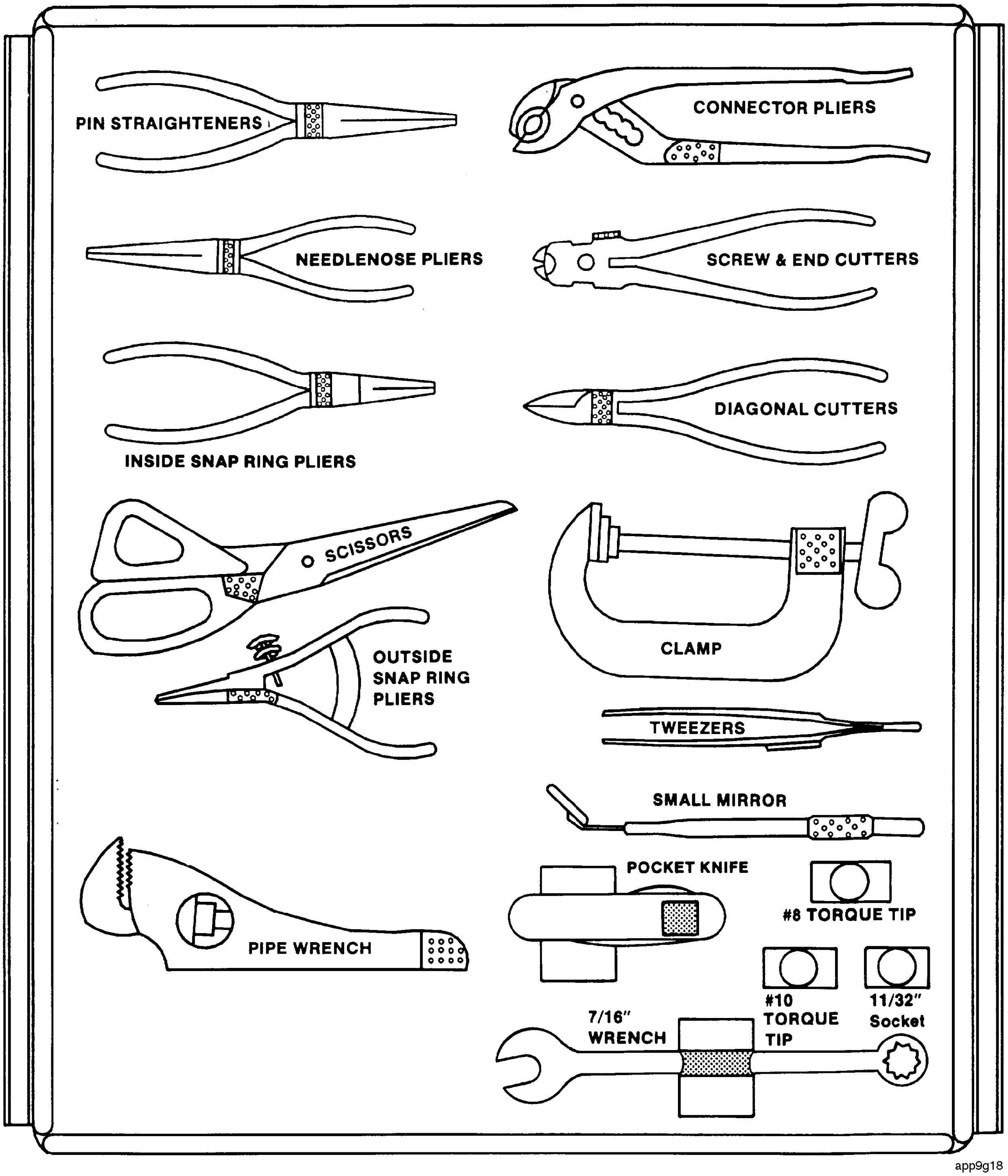


Figure 6-12.- Drawer 3, Spacelab tools (typical packaging).

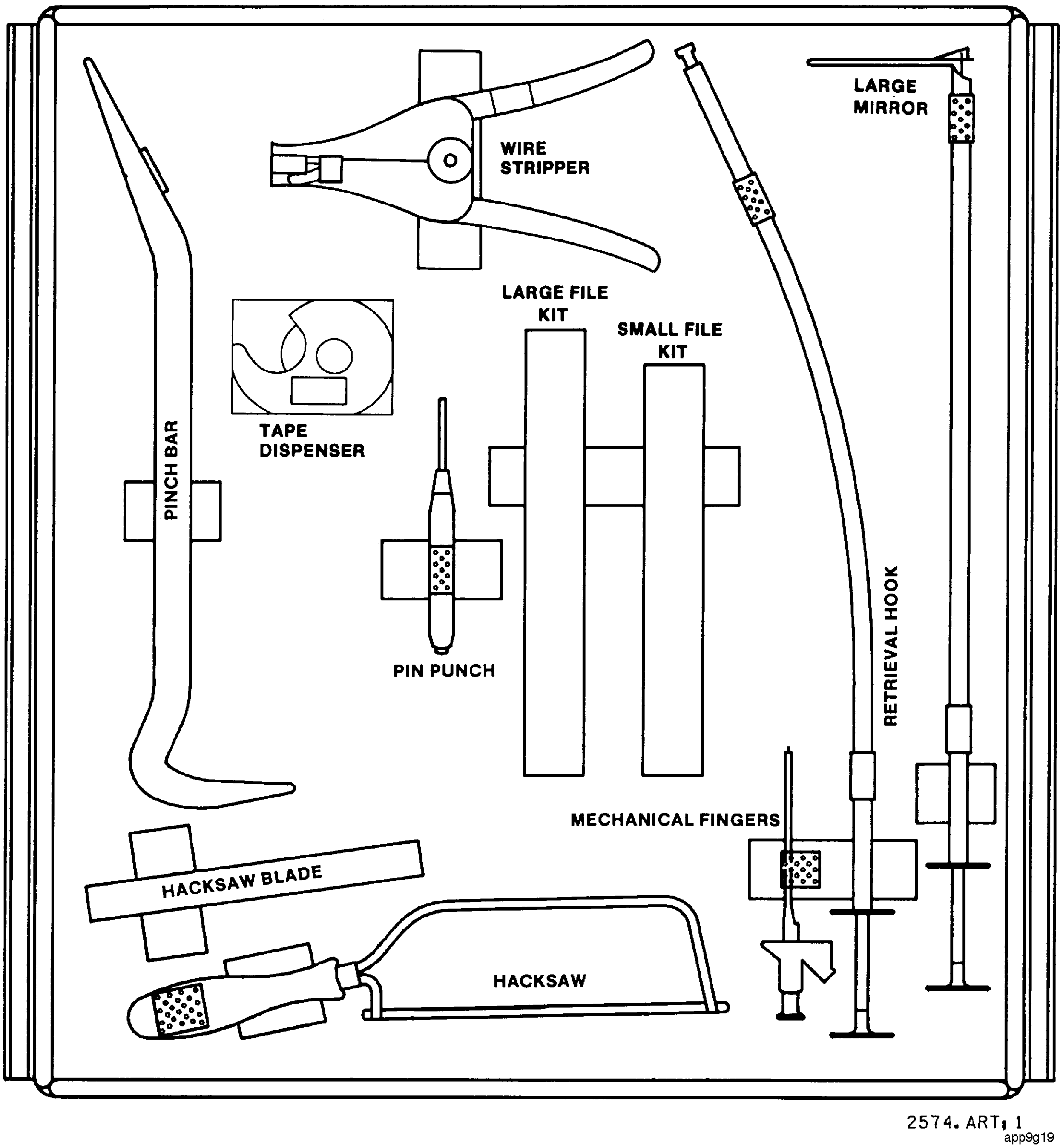


Figure 6-13.- Drawer 4, Spacelab tools (typical packaging).

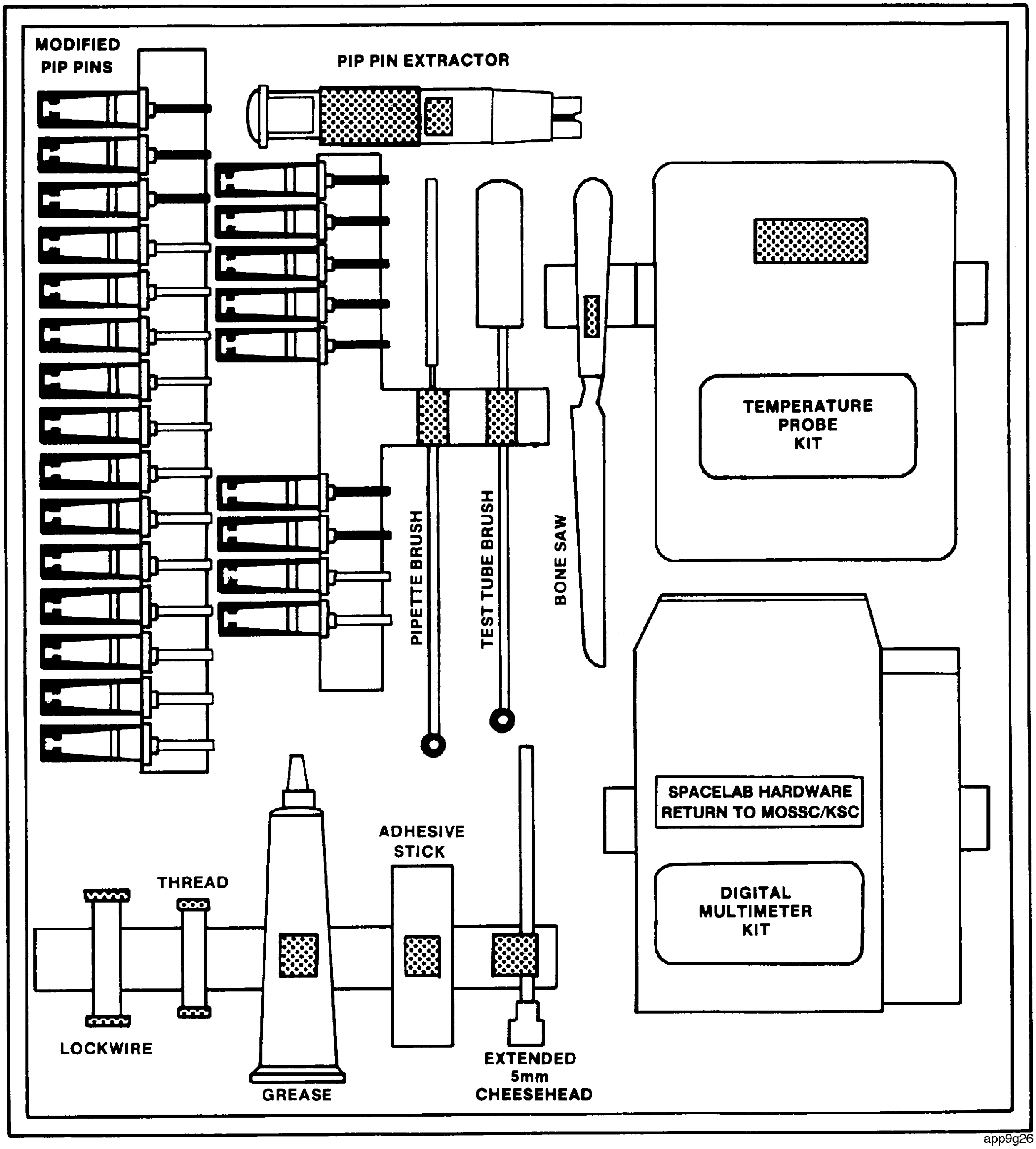


Figure 6-14.- Drawer 5, Spacelab tools (typical packaging).

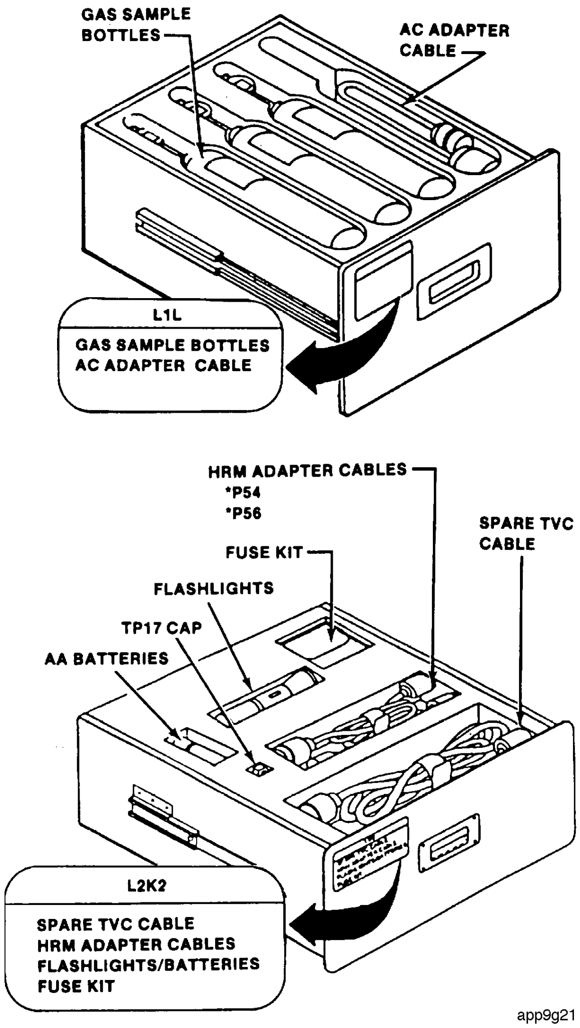


Figure 6-15.- Additional Spacelab equipment (tpyical packaging).

6.12.1 Inflight Maintenance Procedure Development and Verification

Detailed payload IFM procedures for customer-supplied habitable modules will normally be developed by the customer. When an IFM task has a safety impact on the crew or orbiter, it is considered an SSP procedure and will be developed by the SSP in consultation with the customer.

Use of SSP payload mockups and Space Shuttle trainers by the customer to develop payload-unique IFM techniques and procedures is an optional service. The SSP facility resources available for payload IFM development activities include the crew compartment trainer and/or the WETF for preliminary evaluation of access and stowage, and the Shuttle Avionics Integration Laboratory (SAIL) for electrical and functional interfaces. Utilization requirements for these facilities will be documented in the PIP.

SSP mockups of Space Shuttle flight vehicles and flight vehicle trainers may also be used by the customer for developing payload IFM procedures. When mockups are not available, flight vehicles (e.g., Spacelab) may be used for IFM payload procedure development by the customer as an optional service.

Flight vehicles shall be used to verify IFM procedures. Requirements for verification of IFM procedures at John F. Kennedy Space Center (KSC) will be documented in Payload Verification Requirements Annex, PIP Annex 9.

6.12.2 Crew Training

Requirements and schedules for crew training on payload-specific IFM tasks at customer and NASA facilities will be documented in PIP Annex 7.

Detailed payload IFM procedure crew training for customer-supplied habitable modules will normally be conducted by the customer using high fidelity payload mockups and trainers, and training articles with a level of fidelity appropriate to the complexity and criticality of the task. When a task has a safety impact on the crew or orbiter, it is considered an SSP procedure and training is conducted by the SSP.

SSP mockups and flight vehicles (e.g., orbiter, Spacelab, Spacehab, CDSF) may be used for IFM training activities. Customer-developed hardware required for training shall be located at a site mutually agreeable to the SSP and the customer so that hardware is readily accessible to the crew and flight control personnel.

Selected Space Shuttle crewmembers (commander, pilot, mission specialist) on each flight receive payload IFM training as part of their normal training program. Requirements and schedules for mission-specific payload IFM training will be specified in the flight-specific crew training plan prepared for the mission by the SSP. Payload specialists will receive training as outlined in Payload Specialist Flight Preparation Plan, JSC 23194.

6.13 Documentation

Data related to detailed payload customer IFM requirements, tasks, procedures, and equipment for individual payloads and experiments are delineated in the PIP annexes as follows:

- Annex 1 - Payload Data Package - IFM payload/experiment configuration, schematics, photographs and drawings
- Annex 2 - Flight Planning - IFM information required to accomplish flight planning and timelining for scheduled IFM tasks, and any IFM photo/TV requirements
- Annex 3 - Flight Operations Support - Identification of all IFM tasks and procedures for conducting experiment and payload IFM procedures, go/no-go criteria for flight implementation, unique wiring diagrams, photographs and schematics specifically related to IFM tasks, payload data requirements, and required tools or support equipment
- Annex 6 - Crew Compartment - IFM crew interface, configuration, labeling, and stowage requirements
- Annex 7 - Training - IFM training activities, payload modeling and mockup requirements
- Annex 9 - Payload Verification Requirements - Requirements for any payload IFM procedure verification to be conducted at KSC

Inflight Maintenance Requirements and Constraints

7

7.1 General

This section presents requirements which enable on-orbit maintenance of Space Shuttle payloads to be conducted safely, efficiently, and effectively.

The payload should be designed for reliability and redundancy so that IFM is unnecessary. However, payload/experiment design may permit on-orbit maintenance of systems, including preventive maintenance, corrective maintenance, and limited on-orbit repair. On-orbit repair will be provided as a basic capability. However, it should not levy excessive additional requirements on the Space Shuttle or payload crew.

In the following subsections, payload/ experiment design requirements include the word “shall“and are listed first within each section. Payload customers who elect to utilize IFM services must design to meet these requirements.

Recommended design practices follow the requirements and include the word “should“. Payload customers are urged to comply with these design goals in addition to those specified in NASA-STD-3000 to achieve hardware designs consistent with SSP operations and which support efficient, productive, and safe crew interfaces.

7.2 Hardware Design

a. Sufficient installation tolerance shall be provided so that hardware removal or installation is not hindered by pressurized volume deformation or reboost loads.

b. Sharp edge criteria (as previously described) shall apply to all hardware and structures accessible to the crew (see Figure 5-2).

c. Voids where small parts or debris may lodge shall be covered.

d. Access panels shall be designed to not bear structural loads.

e. Delicate hardware shall be located where it will not be damaged during maintenance operations.

f. Captive fasteners shall be used on removable panels and components.

g. Use of Lock-Tite or other adhesive material on any clamp or mounting fastener shall be avoided.

h. Use of permanent fasteners (e.g., rivets) on removable components shall be avoided.

i. The fewest number of mounting fasteners shall be used to meet strength, integrity, and vibration requirements.

j. Quick release clamps or latches shall be used where possible.

k. Debris covers or filters shall be used on all fans.

7.3 Accessibility

a. Critical hardware shall be easily accessible to the crew.

b. Access covers which open for maintenance shall not be obstructed from opening completely, nor obstruct displays and controls when completely opened.

c. Each LRU shall contain readily accessible power-down switches to isolate it prior to removal.

d. Fuses and circuit breakers shall be easily accessible.

e. All fuses shall be grouped into a minimum number of central, readily accessible locations.

f. Ample clearance shall be provided for connecting or disconnecting electrical, environmental, communications, or plumbing connections.

g. Access shall be provided to all wire segments and connectors.

h. Easy access to the interior of LRU's shall be required.

i. Clamps (e.g., harness clamps) shall be located so that clamp closures and mounting fasteners are readily accessible.

j. Removal of any LRU or access panel should not require the removal of another LRU or access panel.

k. Access covers which cannot be fully removed should be capable of locking in the full open position.

l. Ground or retention wires used on pushbutton indicators should be long enough to ensure access to the back of the indicator.

m. Access to main wire bundles should not require removal of LRU's.

n. Removal of other LRU's should not be required to connect or disconnect any electrical connector.

o. When practical, removal of no more than one access panel should be required to access an individual wiring harness segment or its connectors.

p. Where practical, equipment drawers or racks should pull, roll, or slide out.

q. Panel mounting fasteners should not require more than one turn to unfasten.

r. The number of turns required to unfasten LRU mounting fasteners should be minimized.

s. Test points (e.g., ground support equipment (GSE) test ports) should be easily accessible and identified.

7.4 Modularity

a. Where practical, LRU's should be composed of modular components to expedite repair.

b. Spare modular components should be provided for critical LRU's.

c. Guide pins and alignment marks should be used to ensure proper installation orientation, afford easy module insertion into electrical components and/or connectors, and minimize pin damage potential.

7.5 Commonality

a. Common tools shall be used. The need for special tools shall be minimized.

b. Common labeling shall be used.

c. The same type of identifier (e.g., location or function decals) shall be used for all hardware.

d. Identification labels shall be located in the same place on similar hardware.

e. Components used for the same function throughout the design should be interchangeable.

f. Similar LRU's should have common mounting provisions.

g. The same type of fasteners should be used for access panels.

h. Similar fasteners of different lengths should not be used in the same installation.

i. The same type of connector should be used for similar functions.

j. Common twist lock connectors should be used for all electrical and communications connectors.

k. Similar plumbing connections should be incorporated throughout the design.

7.6 Identification and Labeling

a. Hardware and assemblies shall be labeled with name, part number, and serial number. If possible, labels shall be visible when installed.

b. Caution and warning labels shall be affixed to equipment where necessary to inform of critical service conditions, hazards, etc.

c. Access covers shall be labeled to identify all equipment behind the cover.

d. Wiring and wiring bundles shall be color coded and labeled as specified in Wiring, Aerospace Vehicle, MIL-W-5088K.

e. Electrical connector part numbers and pins shall be easily readable.

f. Electrical jacks and plugs shall be labeled appropriately (e.g., J-1, P-1), and labels shall be readable when connectors are mated.

g. All pins on each electrical connector shall be identified.

h. Plumbing lines shall be labeled and color-coded as specified in Markings, Functions and Hazard Designations of Hose, Pipe, and Tube Lines for Aircraft, Missile, and Space Systems, MIL-STD-1247B.

i. All fuses shall be labeled for easy crew identification.

j. Identification markings should be provided for each test point and GSE fitting.

7.7 Electrical

a. Space for bends, strain relief loops and service loops in all wire bundles shall be provided to ease installation and/or removal.

b. Cable service loops shall be provided to permit movement of sliding chassis or hinged doors.

c. Cables shall be routed so that they are not pinched by doors, lids, or slides.

d. Exposed wire bundles shall be protected from accidental nicking, kinking, cutting, or fraying.

e. Cables shall be routed to avoid sharp bends.

f. Cables shall be protected from exposure to fluids.

g. Cables shall be protected from exposure to high temperatures.

h. The number of clamps in any one wire bundle shall be minimized.

i. Cabinets shall be designed to avoid cable connections on the front panel.

j. Easily identifiable spare fuses shall be provided for system components.

Acronyms and Abbreviations

8

A	ampere(s)
ac	alternating current
ACCU	audio central control unit
ANSI	American National Standards Institute
ARS	Atmosphere Revitalization System
ASSY	assembly
CB	circuit breaker
CDR	Critical Design Review
CDSF	Commercially Developed Space Facility
CFR	Code of Federal Regulations
cm	centimeter(s)
CWS	caution and warning system
dB	decibel
dc	direct current
DP	deep
ECLSS	Environmental Control and Life Support System
EVA	extravehicular activity
ft^3/min	cubic feet per minute
g	gravity
GPC	general purpose computer
GSE	ground support equipment
HDRR	high data rate recorder
HRM	high rate multiplexer
Hz	hertz
ICD	interface control document
ICRS	intercom remote station
IDD	interface definition document
IFM	inflight maintenance
IN.	inch(es)
IVA	intravehicular activity
KSC	John F. Kennedy Space Center
LRU	line replaceable unit
m	meter
m^3/min	cubic meters per minute
MCC-H	Mission Control Center-Houston
mm	millimeter(s)
MTBF	mean time between failures
mW/cm^2	milliwatts per square centimeter
N	newton
N/m^2	newtons per square meter
NASA	National Aeronautics and Space Administration
NC	noise criteria, noise curve
NR	noise rating
OMS	orbital maneuvering system
PDR	Preliminary Design Review
PIP	Payload Integration Plan
RF	radio frequency
SAIL	Shuttle Avionics Integration Laboratory
SSP	Space Shuttle Program
TV	television
TVC	television camera
V	volt(s)
Vdc	volt(s) direct current
V/m	volts per meter
WCCU	wireless crew communications unit
WETF	Weightless Environment Training Facility
YEL	yellow

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9

JSC

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3. JSC 22359, Crew Scheduling Constraints (Appendix K of the Space Shuttle Crew Procedures Management Plan), Mission Operations Directorate, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Defines major criteria for use of crew time for scheduled activities, flight rules decisions, nominal real time preplanned activities, and other crew activities.

4. JSC 23194, Payload Specialist Flight Preparation Plan, Training Division, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Addresses the requirements necessary to prepare a training specialist for a Space Shuttle mission.

5. NASA-STD-3000, Man-Systems Integration Standards, Man-Systems Division, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Provides man-systems design considerations and example design solutions which are consistent with SSP operations and support safe and efficient crew interfaces with the orbiter and within the Space Shuttle flight environment.

6. NHB 8060.1, Flammability, Odor, and Offgassing Requirements for Materials in Environments that Support Combustion, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Establishes maximum limits for crew exposure to toxic trace gases and other chemical contaminants.

7. NSTS 07700, Volume XIV, Space Shuttle System Payload Accommodations, Space Shuttle Integration and Operations Office, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Provides an overview of Space Shuttle accommodations to support payload design and integration. This document, its attachment, and its appendixes describe the interfaces between payloads and the Space Shuttle.

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10. NSTS 14046, Payload Verification Requirements, Space Shuttle Program Office, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Establishes basic requirements for the SSP customer verification program, PIP Annex 9 requirements, and requirements for certificate

of compliance submittal by the customer and/or NASA during the verification process.

11. NSTS 18468, Mission Integration Control Board Configuration Management Procedures, Space Shuttle Program Office, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Establishes detailed configuration management procedures for control of program level requirements formally delegated to the Mission Integration Control Board.

12. NSTS 21000-IDD-MDK, Shuttle/Payload Interface Definition Document for Middeck Accommodations, Space Shuttle Integration and Operations Office, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Defines and controls payload/ middeck interfaces and constraints.

13. PIP Annex 1, Payload Data Package, Space Shuttle Integration and Operations Office, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Identifies payload configuration, mass properties data, schematics, drawings, photographs, and RF radiation data.

14. PIP Annex 2, Flight Planning, Space Shuttle Integration and Operations Office, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Contains IVA information required for flight planning and timelining of IVA tasks, attitude and pointing constraints, and photo/TV requirements.

15. PIP Annex 3, Flight Operations Support, Space Shuttle Integration and Operations Office, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Identifies payload operations support plans and defines flight operations decisions, joint operations interface procedures, and malfunction procedures. Includes electrical power and command interface drawings.

16. PIP Annex 6, Orbiter Crew Compartment, Space Shuttle Integration and Operations Office, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Identifies crew interfaces, displays and controls, panel configuration and labeling, stowage requirements, translation paths, and module configuration layout.

17. PIP Annex 7, Training, Space Shuttle Integration and Operations Office, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Identifies IVA training activities, payload modeling, and mockup requirements.

18. PIP Annex 9, Payload Verification Requirements, Space Shuttle Integration and Operations Office, Lyndon B. Johnson Space Center, Houston, Texas (current issue). Contains requirements for any payload IFM procedure verification to be conducted at KSC.

NASA Headquarters

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Department of Defense

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22. MIL-W-5088K, Wiring, Aerospace Vehicle, Systems Engineering and Standardization Department, Naval Air Engineering Center, Lakehurst, New Jersey. Specifies design requirements for aerospace vehicle wiring.

General Services Administration

23. Federal Standard 595, Colors, General Services Administration, Washington, D. C. Establishes color coding guidelines for identifying systems, indicators, controls, and situations with advisory, cautionary, safety-related, hazardous, emergency, and other applications onboard the shuttle.

Office of the Federal Register

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